

The AMSAT Journal

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CONTENTS

New Satellites in Orbit 1

Apogee View: 3
By Bill Tynan, W3XO

The AMSAT Phase 3D
Spacecraft 4
By Dick Jansson, WD4FAB

AMSAT Field Day, 1993 ... 12
By John Hansen, WAØPTV

Groundstation
Diagnosis 15
By Buzz Gorsky, WH6I

Heard on the Downlink ... 17
By John Hansen, WAØPTV

AMSAT News 18

Satellite Orbital
Elements 19
By Ray Hoad, WA5QGD

Spacecraft Engineering
Bibliography 20
By Walter Daniel, KE3HF

An Amateur Satellite
Operation Upgrade
Path 24
By G. Gould Smith, WA4SXM

Principles of HELAPS
Transponder Amplifiers ... 27
By Jan King, W3GEY

New Satellites in Orbit

KITSAT-B, ITAMSAT, EYESAT, Others, Successfully Launched

The number of Orbiting Satellites Carrying Amateur Radio continues to grow by leaps and bounds as the Ariane 40 V59 mission appears at this writing to have been a complete success. On September 26th at 01:45 UTC the latest Ariane mission lifted off from Kourou, French Guyana. At 02:08 UTC the Korean Spacecraft KITSAT-B separated from the ASAP platform. Then a couple of minutes later the first Italian amateur radio satellite, ITAMSAT, and its U.S. twin EYESAT (which carries the AMRAD-OSCAR amateur payload) separated.

Early reports indicated that the new satellites have survived launch and separation with no damage. Signals from all the satellites were strong but showed the fading typical of tumbling newborn satellites. KITSAT-B is to become KITSAT-OSCAR 25 (KO-25), while ITAMSAT will be Italy-OSCAR 26 (IO-26) and EYESAT will be AMRAD-OSCAR 27 (AO-27).

KITSAT-B, which belongs to the Korean Institute of Technology, is similar to KITSAT-A (KO-23) and will be used for digital store and forward communication at 9600 baud FSK. ITAMSAT is capable of both 1200 baud PSK and 9600 baud FSK digital communication. Both of these satellites will be accessed using the standard PG/PB groundstation software. The AMRAD payload is designed mostly for experimentation rather than routine communications.

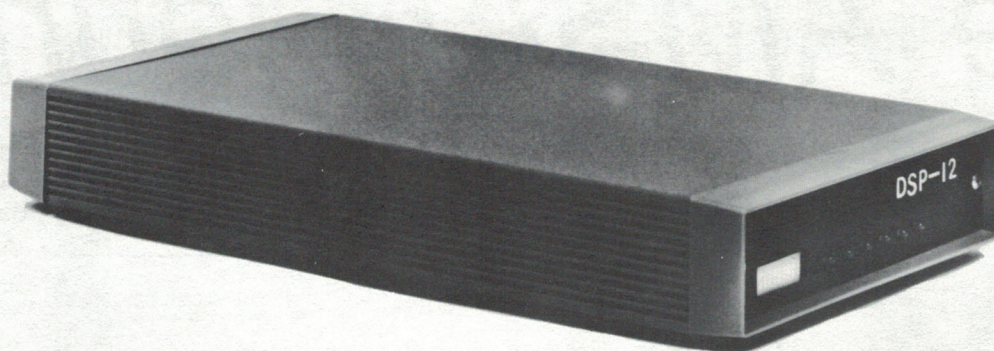
Details of the new satellites' capabilities including up and downlink frequencies can be found in the July/August issue of *The AMSAT Journal*. Preliminary Keplerian elements for these satellites are included in this month's table provided by Dick Campbell. As is usual with Keplerian elements from new satellites, revisions will be made fairly frequently, so check ANS, amsat.org on the Internet, or the AMSAT-NA BBS's for additional information.

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An Important Year for the Amateur Space Program

by Bill Tynan, W3XO
President, AMSAT-NA

This is a very important year for the amateur radio space community and for AMSAT-NA in particular. It is the year that, after several years of planning, construction actually began on the most challenging amateur spacecraft yet - Phase 3D. But, in addition, we now have three, and possibly four, new amateur satellites launched on the Ariane V-59 mission September 26th.

The reason I hedge on the number is that we are still awaiting a decision on the part of the Portuguese builders of POSAT as to whether they are going to activate the amateur system on that satellite. If they do, we should be able to capture some exciting earth images. As this is being written, KITSAT-B has been christened KITSAT-OSCAR 25 (KO-25). ITAMSAT has been given the name ITALY-OSCAR 26 (IO-26) and EYE-SAT is now known as AMRAD-OSCAR 27 (AO-27). If anyone is confused by the designation AO-26 standing for AMRAD rather than AMSAT, I will remind them that the first AO was AO-5, which stood for Australis OSCAR 5; not AMSAT OSCAR 5! Why AMRAD? AMRAD is an experimentally minded amateur radio club in the Washington, DC area. This group is responsible for the amateur package on EYESAT, which is otherwise a commercial spacecraft. The launch of these new OSCARs has generated the same kind of excitement and challenge which we experienced in January 1990 with the launch of the first four MICROSATs and UO-14.

Although the Phase 3D spaceframe, constructed in Germany during the summer, is not the one intended to be flown on the big new Ariane-5 launch vehicle in April 1996, it does represent an important milestone in the actual construction of this ambitious spacecraft. It is the first hardware produced in the long and involved task of building the satellite. First, it an-

swers a lot of detailed design questions and confirms that the hundreds of drawings, slaved over so long by WD4FAB, are correct and sufficient to produce flight hardware. Second, it may very well serve as a backup, or second, spaceframe if such is ever needed. In addition, over the past few months, actual design work was begun on various electronic modules. Several German teams are hard at work designing and building transmitters for 70 cm and 13 cm and receivers for 2 meters, 70 cm and 23 cm. A Finish group is making good progress on a 10 GHz transmitter and have shown "brassboard" hardware. A Belgian group has stated its intention to construct a 24 GHz transmitter. As previously noted, the South Africans have signed up to provide a 10 meter bulletin transmitter. Work on the IHU (central spacecraft computer) has also begun in Germany. By now, everyone has heard that a 2 meter transmitter is to be built in Great Britain. This effort is now also underway. In addition, Jim Hendershot, WA6VQP, is continuing work designing a 2 meter transmitter. With two well qualified people independently working on this challenging task, we have all the more chance of achieving a flyable product.

Yes, Phase 3D has finally begun the transition from an idea on a blackboard to actual hardware. That does not mean that its successful completion is a foregone conclusion. There is a long way to go and additional competent electronic and mechanical designers and builders are still needed to assure a completed satellite. The GPS and master oscillator subsystems are examples. W3IWI is just now assembling a team to turn his concepts into suitable flight hardware. There may also be a need for someone to provide a 5.7 GHz receiver.

The other reason why this is an important year is that AMSAT-NA is making a

(continued on page 11)

The AMSAT Phase 3D Spacecraft

by Dick Jansson, WD4FAB

Editor's Note: This paper was originally presented at the AMSAT-NA Space Symposium, October 1993 in Arlington, Texas.

Introduction

The AMSAT International Phase 3D (P3D) Spacecraft Program took an unwanted backward step, in November 1992, as a result of the decision by the European Space Agency, ESA, to withdraw the use of the $\phi 1920$ mm launch vehicle interface, both of the bolted and separable designs. This calamitous event totally trashed the "Falcon" spacecraft design that was about to be constructed at Weber State University in Ogden, Utah.

Rising from the ashes of the events of November 1992, the multi-national P3D Project Team has now created a spacecraft design that is much more likable and workable. Team members will also appreciate the improved access to their units contained in the sides of the spacecraft. AMSAT-DL and AMSAT-NA workers have completed their basic efforts to construct an Engineering Model spaceframe in Marburg, Germany, working with Project Leader, Karl Meinzer, DJ4ZC, and Konrad Miller, DG7FDQ. The US participants of this team are now applying the resulting spacecraft design and fabrication experience in fabricating a Flight Model spacecraft at Weber State University, Ogden, Utah. The Utah group is lead by Ralph Butler and Jaim Parsons. This paper will discuss some of the construction experiences of this summer 1993.

Launch Vehicle Interface

Fig.1 illustrates the payload sections of the Ariane AR502 vehicle, showing that P3D could be launched from either the upper or lower launch positions. Basically, the plan is to simply raise one of the conical Adaptor sections, used to attach a payload spacecraft to the launch vehicle, spacing it with a cylindrical section, Fig.2. This cylinder is called a $\phi 2624$ Specific Bearing Structure (SBS). Mounted to the top of the SBS is an ESA-provided separation section, the $\phi 2624$ ACU. This, in turn, supports the 1194V Adaptor and its attached spacecraft. This arrangement

provides the P3D a volume of $\phi 2300 \times 750$ mm, including the P3D separation system.

The P3D spacecraft is designed to fit within a volume of $\phi 2300 \times 675$ mm. There is 75mm allowed on the bottom for the separation hardware and omnidirectional antennas. On the top there is an additional 310mm for the main antennas and propulsion motor. Fig.3 shows the composite three-dimensional view of the P3D spacecraft and the SBS, ACU and Adaptor. Also shown are representations of a P3C (AO-13) and a PACSAT (AO-16) spacecraft.

$\phi 2624$ SBS

The preliminary design of the $\phi 2624$ SBS is shown in Fig.4. The design uses a rather unsophisticated sheet aluminum structure with internal stiffening stringers and machined rings, or Frames for bolting to adjacent structures. Internal sheet metal structures are located in three places to support the P3D and its separation system. These details are shown in Fig.5, and show two possible separation pyrotechnic options.

A considerable effort has been made to create usable engineering analyses of the structural characteristics of the SBS. Basically, it meant that I had to return to the 'books' to re-learn engineering methods long lost, and bring them into the modern world of computer analysis. I also found that the computer software far exceeded the capacity of the personal computer being used. My equipment had to go through a very serious upgrading to permit operating high-speed PC units for many hours at a time for "number crunching". There are many days that even the newly acquired 80386/80486 computer facility is never off, being required to operate a 24 hour day on long analyses.

Structurally speaking, we are designing to have the first structural lateral resonant

frequency greater than 30 Hz. This high a frequency gives us a very safe high-value Buckling Factor (BF). Under these constraints the issue of structural stresses have become so low as to be of little concern, typically 20-35% of material yield strength.

While AMSAT has been basically tasked to construct the $\phi 2624$ SBS, the final construction details are not totally clear. Internationally, AMSAT has an acute labor base shortage, both mechanically and electronically. We barely have sufficient personnel to construct the spaceframe by June 1994, without consideration of the SBS. After June, we may have the next group of students to construct the SBS, but that availability may not agree with ESA requirements, and the issue will need to be resolved.

The Spaceframe

Fig.3 shows many of the basic features of the P3D spaceframe. The structure is a hexagonal cylinder that is 2240mm across the corners. Permanently mounted solar panels are attached to two sides of the spacecraft, centered on the +X direction. The other four sides have deployable solar panels held closely to the frame for the launch and motor burn phases of opera-

A Beginners Guide to OSCAR 13

By Keith Berglund, WB5ZDP

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tion. Upon completion of these propulsive efforts, the spacecraft will be magnetically torqued to stop the initial spinning motion. Once stopped, the spacecraft's internal reaction wheels will provide the motion control mechanization and the solar panels will be deployed as shown.

Underneath the outer skin of this spacecraft there is a lot of detailed structure and many sub-systems. Fig.6 depicts an exploded view of the spacecraft, courtesy of Wilfried Gladisch, the very talented Technical Illustrator of the Marburg group. This shows the radial, sheer-loaded Divider Panels and three concentric hexagonal cylinders, composed of the external Side Panels, Equipment Panels and the Center Panels. Below Side Panels, are the equipment bays and all of the electronic modules. These bays are only 200mm deep and are therefore readily accessible (even by my "short-armed" electronic colleagues).

The next hexagonal cylinder is constructed of the Equipment Panels. These panels have become rather complex structural subassemblies, having the Module

Mounts attached on one side, and one end of the Tank Mounts on the other side. Also mounted on interior side of the Equipment Panels are the Heat Pipes used for the spacecraft thermal control system. The equipment bays can contain up to 36 full sized modules with PC boards of 200x270mm. Only some 28 modules are expected to be flown. Obviously there are some special sized cases, and these will also be discussed.

An important aspect of mounting the Equipment Panels is in achieving a coplanar coincidence of the heat pipe facets with the surfaces of the panels. In the world of sheet metal this is somewhat of a difficult challenge. (An analog would be that of the probability of rolling six 300 Bowling games in a row.) This was considered one of the major goals to be met by the Marburg fabrication of the Engineering Model spacecraft. It was accomplished with precision by the team, certainly a high-point of our effort.

Moving further inside, past the equipment bays, are the propellant bays, with the six spherical Propellant Tanks, Fig.7,

currently being fabricated in Russia. About 46% of the 400kg (881lb.) launch separation mass of P3D will be the liquid propellants needed to get the spacecraft to its final orbit. While in Marburg, the Russian drawings for the tanks were reviewed and some adjustments were made. The drawings forwarded to us were not copies or machine prints, but a second set of hand-drawn originals, made because there are no large copy machines in Russia.

Also mounted in these propellant bays will be the spacecraft's attitude controlling Reaction Wheels and the Battery power storage cells. The Propellant Tanks are also supported on the inner-most hexagonal cylinder by the Center Panels, which provide a hollow internal cylinder for the high-pressure helium tank, routing of propellant lines and accommodating portions of the two motors that will be an intimate part of the spacecraft.

On the top and bottom surfaces of the spacecraft there will be an outer ring of thin aluminum permanently attached to the Divider and Equipment Panels. Inner removable panel sections on the top and



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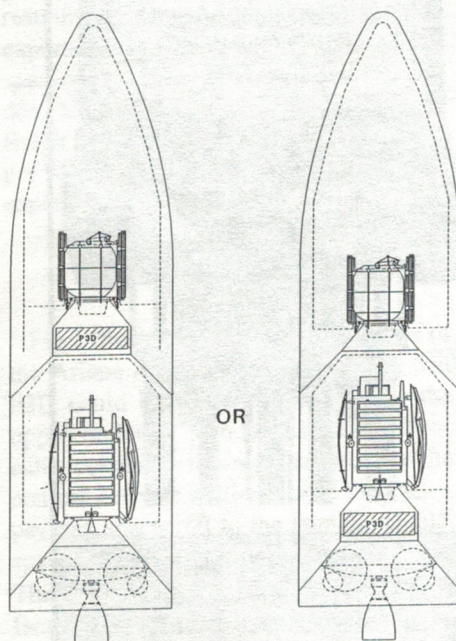
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bottom provide easy access to the propellant bays.

Careful assembly of the various parts and subassemblies will be needed, along with a large quantity of rivets. The machined Corner Posts are products of student labors at Weber State University. It can also be seen that the Heat Pipes have been carefully installed into the holes provided in the Divider Panels. In the fabrication of the Engineering Model of spacecraft, we generated some impressive statistics. In the finished spaceframe, there will be a total of 9,954 holes or drilling operations of some kind. This also means some 19,908 deburring operations. Most of these holes were drilled during our stay in Marburg. The equipment panels alone have 3,282 holes in them, and we did them in just one week with the assistance of the drilling templates provided by the WSU student efforts.

The Engineering Model spacecraft construction effort got to the point of having the principal structural panels fabricated and assembled with the Heat Pipes. The Top Plates (for both top and bottom of the spacecraft) did not get done nor were any of the internal stringers that will be needed on some panels. Konrad Miller will complete these items in the near future.



A502 LAUNCH CONFIGURATIONS

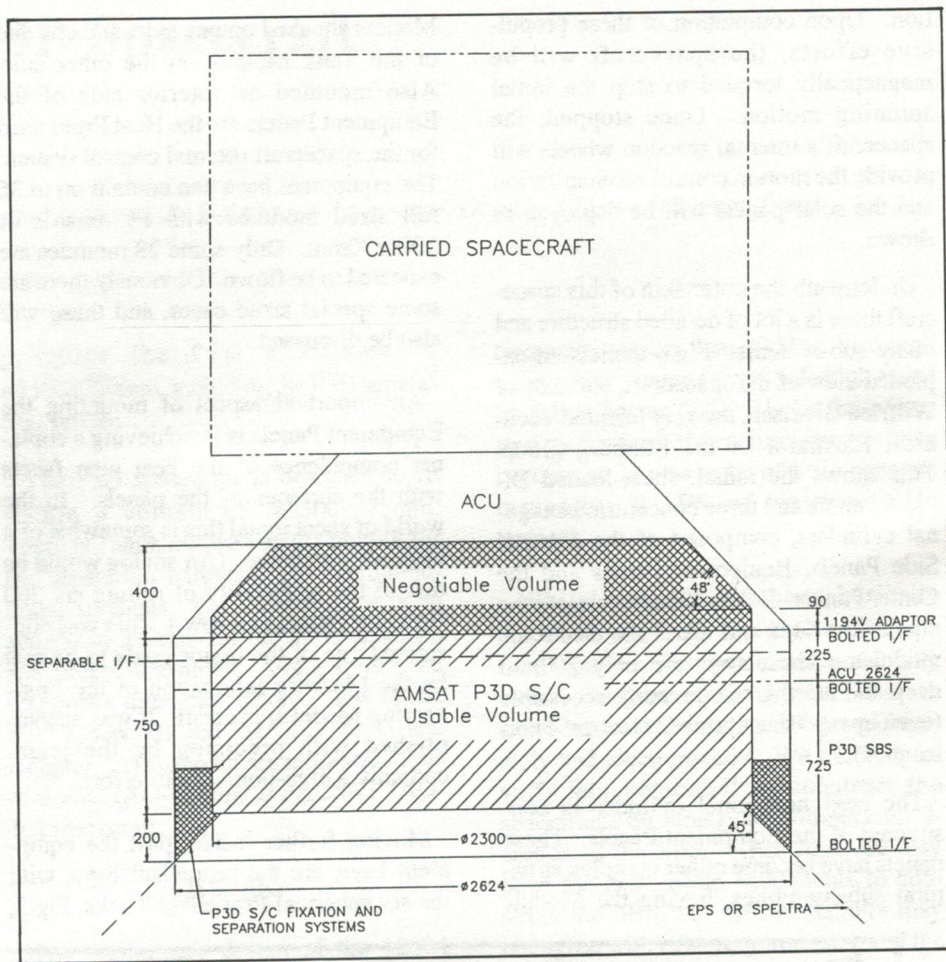


Fig.2 P3D Composite and Usable Volume

Thermal Design

There are steps and technologies that had to be applied to the satellite design long before any of the sheet metal bending activities. One of these is that of the spacecraft thermal design. Construction and launch activities are rather useless if satellite designers fail to deal with the thermal requirements. Several Amateur satellite thermal design failures have been seen in the near and distant past and those design errors need to be avoided.

Our challenge is to keep the equipment on the sun side of the spacecraft from becoming too warm and the equipment on the rear of the spacecraft from becoming too cold. Sizeable amounts of power dissipation from transmitters also needed to be accommodated safely. All of these objectives are being met by the fabrication of only four internally mounted heat pipes. (The Falcon spacecraft used 16 heat pipes.) For the uninitiated, a heat pipe is a tubular device that is an extremely effective transporter of thermal energy over

considerable distances - a super thermal conductor - using anhydrous ammonia as the fluid.

The four Heat Pipes in the spacecraft are mounted to the propellant bay side of each of the six Equipment Panels. This places the Heat Pipes immediately underneath the electronic modules on the spacecraft internal structure. No disassembly of these Heat Pipes will be needed for access to the spacecraft interior and the electronics bays. Fundamentally, these Heat Pipes are used to redistribute the thermal energy uniformly throughout the spacecraft, equalizing the sun and anti-sun side differences, as well as the transmitter power dissipations.

One thermal control method, used on OSCARS 10 & 13, employed insulation blankets, Multi-Layer Insulation (MLI), using a very specific type of thermal insulation for space use. These are messy to construct and use and we want to avoid them on P3D.

We have deliberately changed some of the solar panel precepts of this spacecraft from its predecessor Falcon design. The earlier design planned to have one of its three solar panels fully populated with solar cells, which in turn required that a considerable amount ($\approx 700\text{W}$) of rejected solar heat to be removed from the backside of the panel, in addition to that radiated from the front of the panel. Accomplishing this thermal transport, without creating undue heating of the spacecraft internal components, required the mounting of an array of heat pipes on the exterior surfaces and closely coupled to both the solar panel and adjacent radiator panels. This system would have been complex at best and would have required extensive (read that as messy!) thermal structure disassembly to gain access to the spacecraft interior.

The current design of the P3D also has one-third of its solar panel area as body-mounted units. We have, however, taken deliberate steps to alleviate the need for any backside heat transfer from these panels by only populating these panels with one-half of the solar cells in the available area. The other half of the area has solar reflecting surfaces mounted alternating with the solar cells. These Optical Solar Reflector (OSR) surfaces are actually second-surface quartz mirrors and do a very thorough job of getting rid of unwanted solar energy.

In the thermal design consideration for the spacecraft we will again employ a device that has been quite successful in prior Phase 3 spacecraft. This is the use of a thermally insulating fiberglass channel for mounting the electronic modules. This channel also reinforces the Equipment Panels. This thermal technique isolates modules from thermal conduction heat transfer with the spacecraft. Most modules are quite low power dissipation and they enjoy only modest temperatures. They are isolated from any significant temperature changes of the spacecraft, such as seen from eclipse events. This technique has worked very well in the past and will again be implemented.

Some electronic modules have a high power dissipation, however, and for these situations we have designed a modified module, one that will permit direct mounting to the Equipment Panel and the Heat Pipes. Thus we will have a solid thermal

design with adequate cooling of high power components and the availability of that rejected thermal energy to insure that the spacecraft will not become unnecessarily cooled. A series of thermal tests is being planned with the use of a section of heat pipe and modelling of part of the power module. The data generated will give us some degree of confidence about achievable heat transfer values using some of the materials and surface finishes of interest.

Antennas

One of the subjects that is close to nearly every Radio Amateur, and for which nearly all of us become 'expert,' is that of antennas. We are fortunate that we have the services of one of the more ingenious participants in the P3D program, Stan Wood, WA4NFY. Stan has had no preconceptions about the antennas needed, and has done a large amount of research to find suitable designs. Fig.3 illustrates

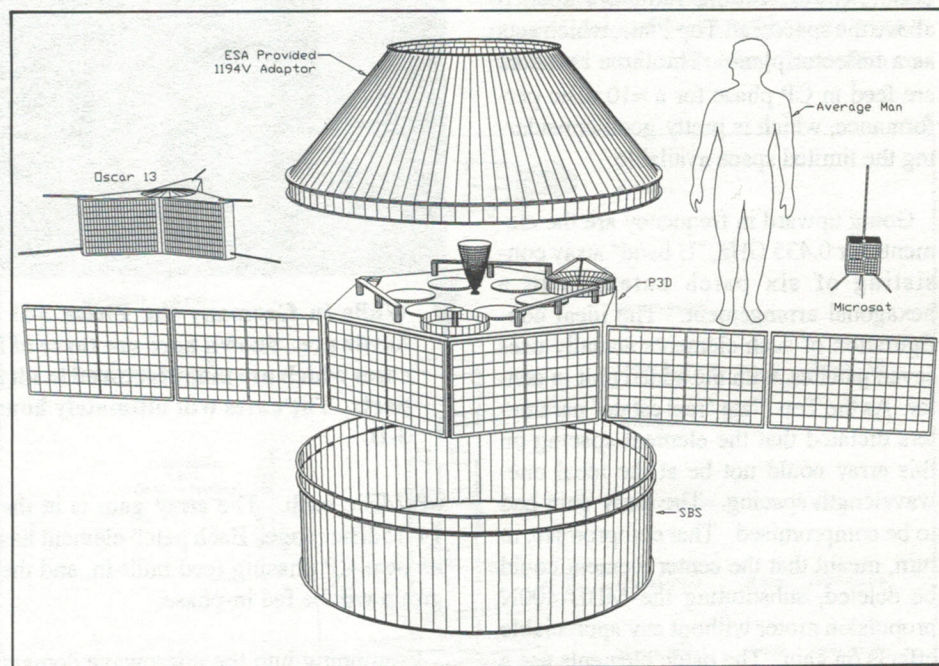


Fig.3, Phase 3D Spacecraft and SBS

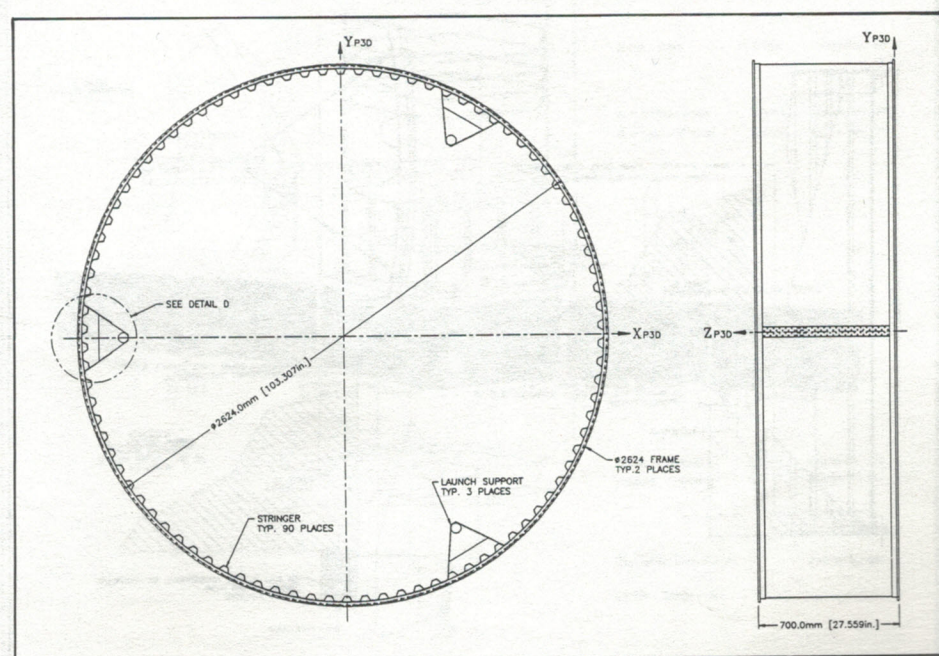
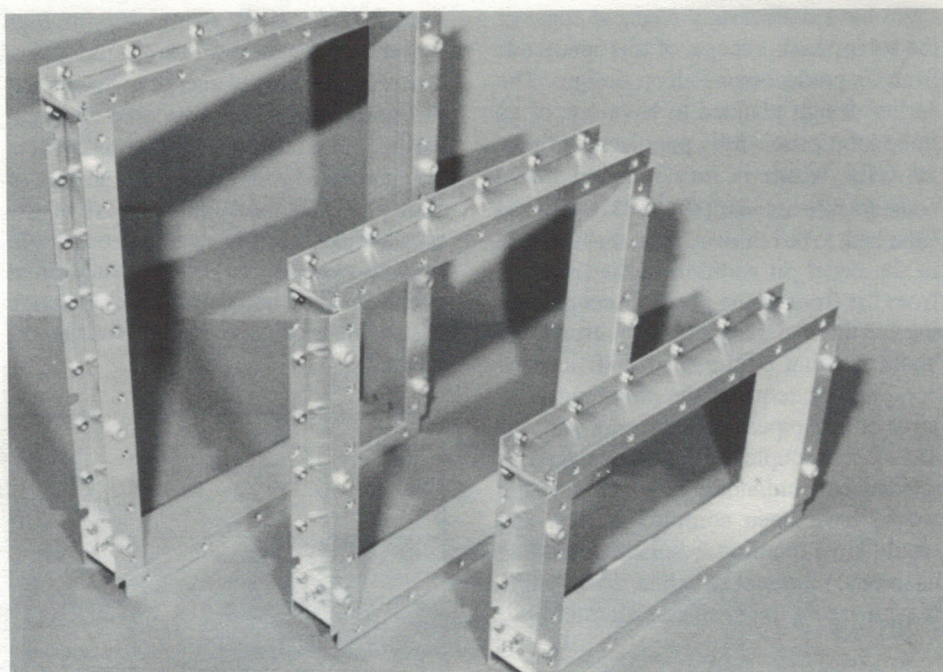


Fig.4 ø2624 Specific Bearing Structure (SBS)

most of this current thinking. Not illustrated, however, is the $\approx 1/4$ wavelength driven element and reflector monopoles for the 0.029 GHz perigee broadcast transmitter. This radiating element uses the spacecraft as a counterpoise and achieves ≈ 3 dBi gain.

Next in line are the 0.145 GHz "V Band" elements, which have caused by far, the greatest amount of work to be done. The design that has been selected uses three double-folded dipole radiators spaced above the spacecraft Top Plate, which acts as a reflector plane. The three radiators are feed in CP phase for a ≈ 10 dBic performance, which is pretty good considering the limited space available.

Going upward in frequency are the elements for 0.435 GHz, "U band" array consisting of six patch antennas in a hexagonal arrangement. The ideal configuration of such elements actually uses seven patches, with the added unit in center. As the Top Plate "real estate" parameters dictated that the element spacing on this array could not be at the ideal one-wavelength spacing. The array gain had to be compromised. That compromise, in turn, meant that the center element could be deleted, substituting the MBB 400N propulsion motor without any appreciable effects on gain. The patch elements use a unity dielectric spacer and achieve nearly full theoretical gain in the range of



While in Germany the Phase 3-D team took delivery of some actual flight hardware. Shown here are three of five different versions of electronic module cases which are manufactured in kit form and contain virtually interchangeable parts. The cases will ultimately house the vital electronic components of Phase 3-D.

≈ 8.7 dBic each. The array gain is in the 14-15 dBic range. Each patch element has its own CP phasing feed built-in, and the group will be fed in-phase.

Continuing into the microwave domain is the 1.27 GHz, "L band" antenna consisting of a design known as a Short BackFire

Array, SBFA. This design has a $1/4$ wave high fence at a diameter of 2 wavelengths. It uses crossed dipole elements on the center post and has a small reflector at a height of $1/2$ wavelength. Gain performance is consistently ≈ 15 dBic. It is expected that the U band and L band antennas will be the work-horse spacecraft receiving elements.

Antennas for the 2.4 GHz, "S band," and 5.6 GHz, "C band," operations will consist of either parabolic reflectors (the C band antenna is not illustrated) or SBFA units. In either case, these designs will permit performances of ≈ 20 dBic, which is the highest that we desire to go and still achieve full illumination of the Earth. This type of performance can be achieved with the space available, using 0.5m for the S band and 0.25m for the C band antennas. The basic consideration for setting the gain for any antenna is that it provides full illumination of the Earth at apogee and that at perigee the signals seen on the Earth limb will be no less than those seen at apogee. The only bands for which these parameters may be of concern are for S, C, X and K. Meeting this criteria is seen as no problem for the lower gain V, U and L bands. Such RF design precepts will allow operating all of these bands without

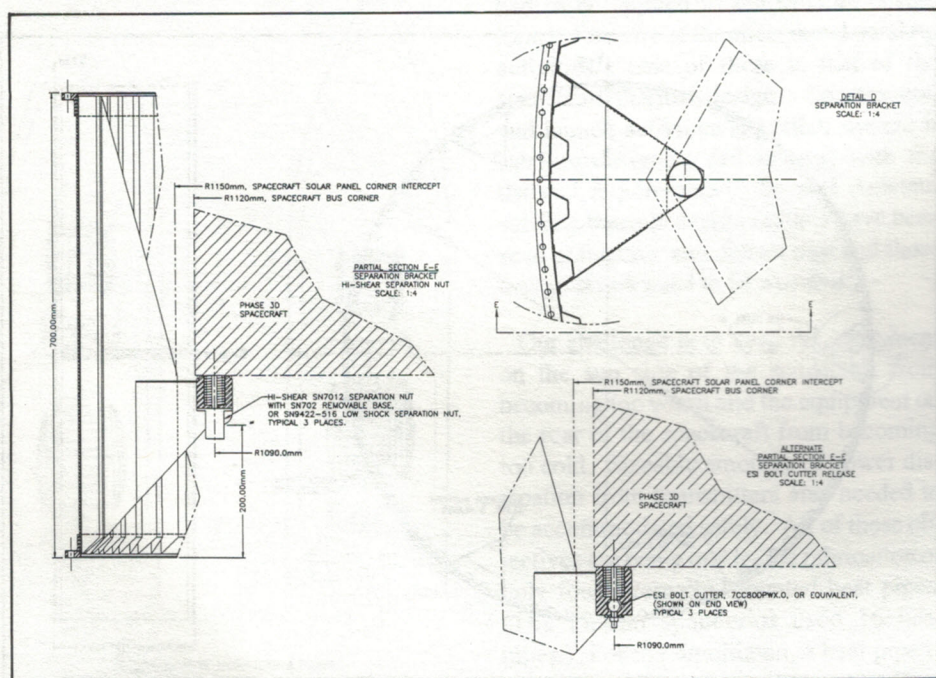


Fig.5. SBS Separation Support Details

the need of any antenna gain switching or changing, keeping with the KISS principles for this spacecraft.

Partially blocked from our view by a V band element in Fig.3 is the horn antenna that will be used by the AMSAT-OH designers for the 10.5 GHz, "X band" transmitter radiator. There may also be a low-powered transmitter on "K band" at 24 GHz. This is seen as the P3D analog to the current S band operation of OSCAR 13.

Omnidirectional antennas for the spinning-mode of spacecraft operation are now being designed. There is a lot of busy 'action' happening on the Top Plate of the spacecraft. Careful selection of candidate antenna designs and management of the area resources will make all of this capability a reality.

Propulsion and Orbit

Getting to the final orbit, where this spacecraft can provide the ultimate service that is intended, will require a substantial propulsive effort. In the terms of the rocket experts, a ΔV about 1800m/s (a propulsion energy term) will be required, resulting in the need for 46% of the spacecraft's separation mass to be high-efficiency propellants. For the principal propulsion, the design is to use the proven 400N (95lb.) thrust DASA (former MBB) hypergolic motor that has been successfully used in two previous Phase 3 missions, OSCAR 10 and OSCAR 13. This approach is well understood, and is not 'broken' so we do not intend to 'fix' it. Fig.8 illustrates the orbital stages that are currently forecast to reach this 16.0 hour final orbit.

The key element in propulsion for the final orbit, and possibly some level of orbital maintenance to avert such disastrous orbital problems as are now forecast for OSCAR 13, is the inclusion of a small Arc Jet motor. This thruster has only a value of 0.1N, but it also operates on only a single fluid, anhydrous ammonia, which can be stored for long periods. The motor uses 1 kW of electrical power to gasify the ammonia to high temperatures, achieving the needed thrust. This operation will happen for about a one hour time period for a number of apogee burns to increase the orbital plane from 60° to the stable

63.4° Molnia orbit. With a spacecraft capacity of up to 80 liters of ammonia, we have a maximum "burn" time of about 452 hours.

Special Modules

In addition to the previously noted special designs needed to adapt high power electronic modules to provide cooling, there are some other cases worthy of note. The X band transmitter has some substantial thermal energy to be dissipated as it will probably have the poorest RF efficiency of all of the transmitters. In addition,

the coupling of the RF output power must be given special consideration as efficient transmission techniques must be used to avoid merely heating the coaxial cable with RF energy. The geometric arrangement of this transmitter assembly will need careful design consideration, as has been recently discussed with the AMSAT-OH team members.

Other modules that have special needs, and also great interest, are the receivers for emissions in the 430,000 GHz region being constructed by JAMSAT. JAMSAT personnel are constructing three such re-

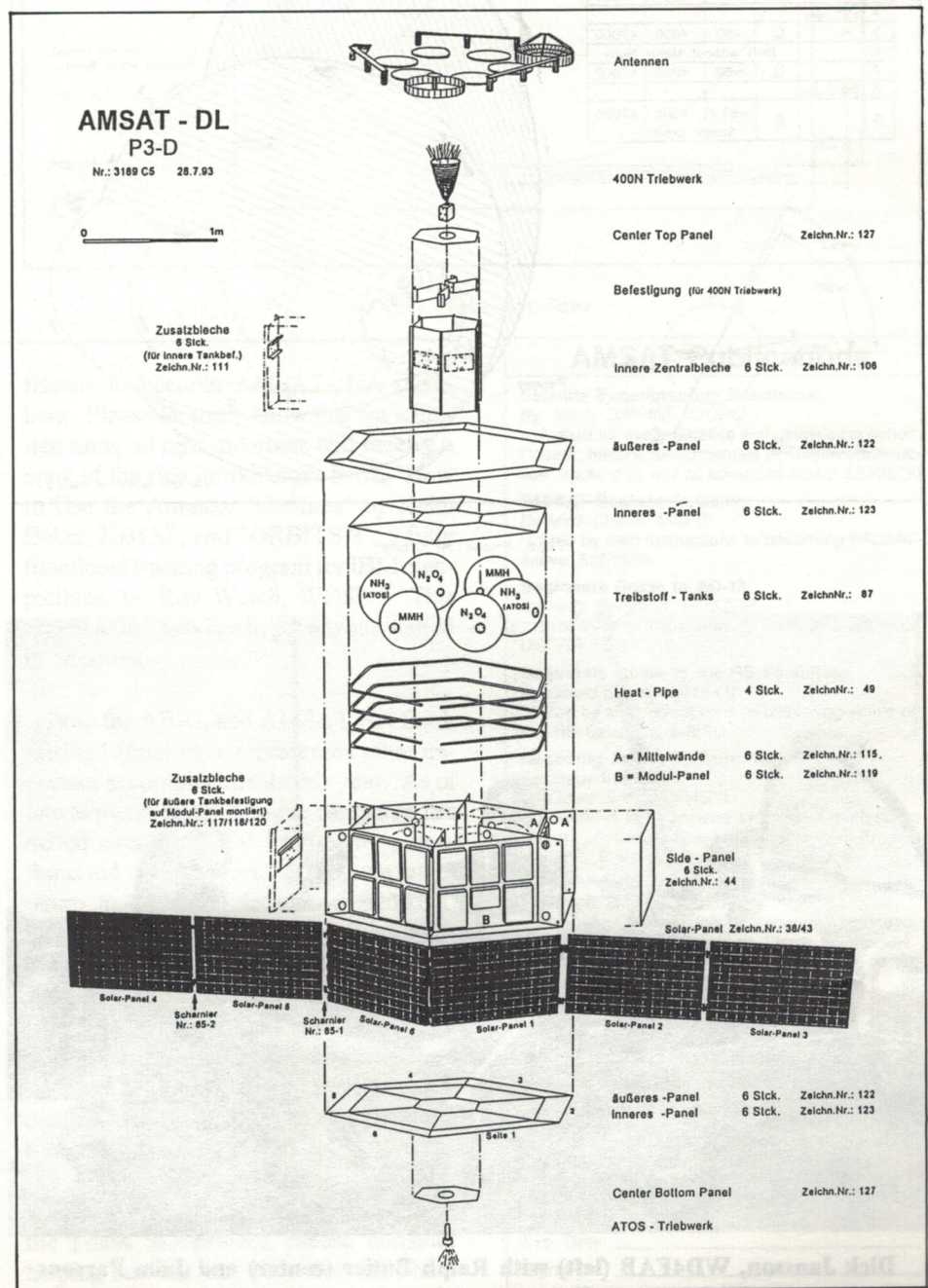


Fig.6, Phase 3D Spacecraft Exploded View

ceivers with different beamwidth receiving antennas. These are the SCOPE experiment cameras, A, B and C. The last of these will have a $\phi 180\text{mm}$ reflective optical system capable of resolving celestial objects. The A and B cameras will be Earth viewing. The placement of the SCOPE C camera will require a special mounting provision and an optical path toward the -X side of the spacecraft, away from both the Sun and the Earth.

Spacecraft Mass

One very hard number in this design is that we must separate from the Ariane 5 at a mass of no more than 400kg. This means that the dry mass of the spacecraft can be no more than 216kg. In early July, Stan Wood totaled a value of up to 310kg, essentially a 100kg problem. The structure has shed some 15kg and is now 52kg. The propellant tanks are now 15kg lighter,

leaving us still with a 60-70kg problem that will have to come from the support equipment and possibly even the experimental payload. Every worker needs to be aware of these problems. There may actually come a day in which some hard decisions will have to be made. Some of the payload may have to be removed from the spacecraft, as was necessary for the ill-fated Phase 3A spacecraft. We may, in the end, not be able to fly some experimenter's favorite package. The highest priorities will obviously be given to the Amateur communications equipment, but even those packages are not totally secure from such truly difficult decisions.

Observations

An intense two months was spent this past summer in Marburg, Germany, with the P3D Project Leader, Karl Meinzer, and his talented group of workers. This P3D project is Karl's creation, and he has substantial support from AMSAT-DL in seeing it through. As the spaceframe construction effort was not electronically oriented, not too much has been noted about the very sizeable effort that has just begun for constructing these modular units. One very key AMSAT-DL participant in this electronic effort is Werner Haas, DJ5KQ, who has worked on Amateur satellites since the early 1970's. There is another group of electronic workers in the Munich area of Germany as well as other units being built in Hungary, South Africa, Finland, Czech Republic, Great Britain and possibly several other countries. Clearly, the major amount electronics on this mission will be constructed in Europe, but they will be housed in module cases machined by the students at Weber State University, Ogden, Utah. This is only a small example of the international cooperation that must be accommodated and acknowledged for this mission to be successful.

The degree of international cooperation that will be required to bring this highly complex spacecraft to final orbit is unprecedented in the history of AMSAT. Quite naturally, the P3D supporters of each participating AMSAT group can take justifiable pride in the accomplishments of their particular group's contribution to the project. We must all remember, however, that this is an international team effort, and that no single group's contributions are

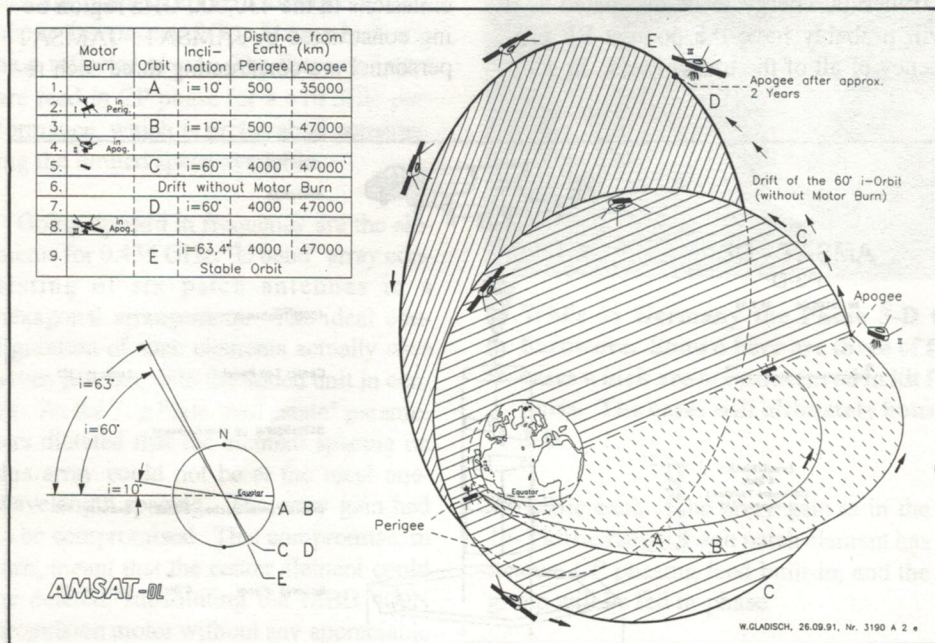
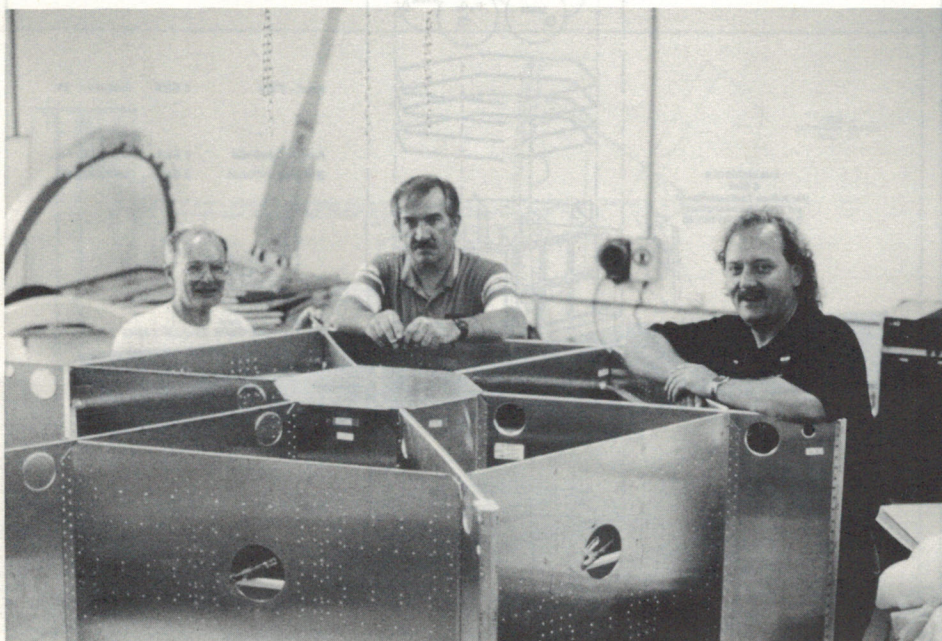


Fig.8, Phase 3D Orbits



Dick Jansson, WD4FAB (left) with Ralph Butler (center) and Jaim Parsons (right) from Weber State University take a break from their work on the Engineering Modem for Phase 3-D.

"more important" than any other. Each piece forms an integral part of the whole. Without each group's contribution, the spacecraft cannot fly. It's that simple.

Phase 3D began as an AMSAT-DL project. AMSAT-NA and other AMSAT groups were cordially invited to join AMSAT-DL in the effort. We in AMSAT-NA accepted the offer and have been spending a lot of time and effort working for that day in 1996 when the P3D spacecraft is finally in orbit. Those of us now busting our rear ends to make the mission a success also know that it is far too complex a project for any one of us to "go it alone".

Conclusion

With all of the radio communications equipment and the special experiments on board the Phase 3D spacecraft, we have a very special spacecraft that can serve the needs of many Amateurs with many interests for a very many years. This is truly a satellite for all Amateurs.

Apogee View:

(continued from page 3)

concerted effort to inform more amateurs about the excitement of amateur satellites and, in the process, expand its membership. This will help assure the future of the organization after the launch of Phase 3D, as well as contribute to that spacecraft's fundraising effort. The ARRL Phase 3D fundraising campaign is a tremendous help. Not only is it meeting its primary objective of raising a substantial amount of money, it is carrying the amateur space program message to nearly 200,000 hams, a significant number of whom are newly licensed. Until the ARRL campaign began, many amateurs had only vaguely heard of AMSAT or the OSCAR satellites. This new awareness, on the part of many more "average" amateurs, is greatly aiding the AMSAT-NA drive to get more hams interested in satellites and recruit new members. A key part of this effort are the AMSAT ads placed in all of the major amateur media promoting the special new member offer. Through these efforts, the entire international amateur space community is becoming an increasingly important factor in Amateur Radio.

You can aid this process, by urging your

friends to become AMSAT-NA members. Please let them know that for a limited time, all new members will receive a copy of the fine introductory book, "How to Use the Amateur Satellites" by Keith Baker, KB1SF, and "ORBITS-2", a fully functional tracking program for IBM compatibles, by Roy Welch, W0SL. This makes a fine package to get anyone started in satellites.

Both the ARRL and AMSAT-NA fundraising efforts have represented other important accomplishments this year. As of late September, the League campaign has netted over \$180,000 from some seven-thousand contributors. Our own campaign has brought in almost \$200,000 from 1,650 AMSAT-NA members. Efforts to raise funds for Phase 3D continue both within Amateur Radio and elsewhere. If you have not yet agreed to do your part in support of the construction of Phase 3D, it's not too late. Give to either the ARRL campaign or the one mounted by AMSAT-NA or both!

Finally, If you have any talents to offer the Phase 3D project, please consider helping out that way too. See the Phase 3D "Help Wanted" column, elsewhere in this issue.

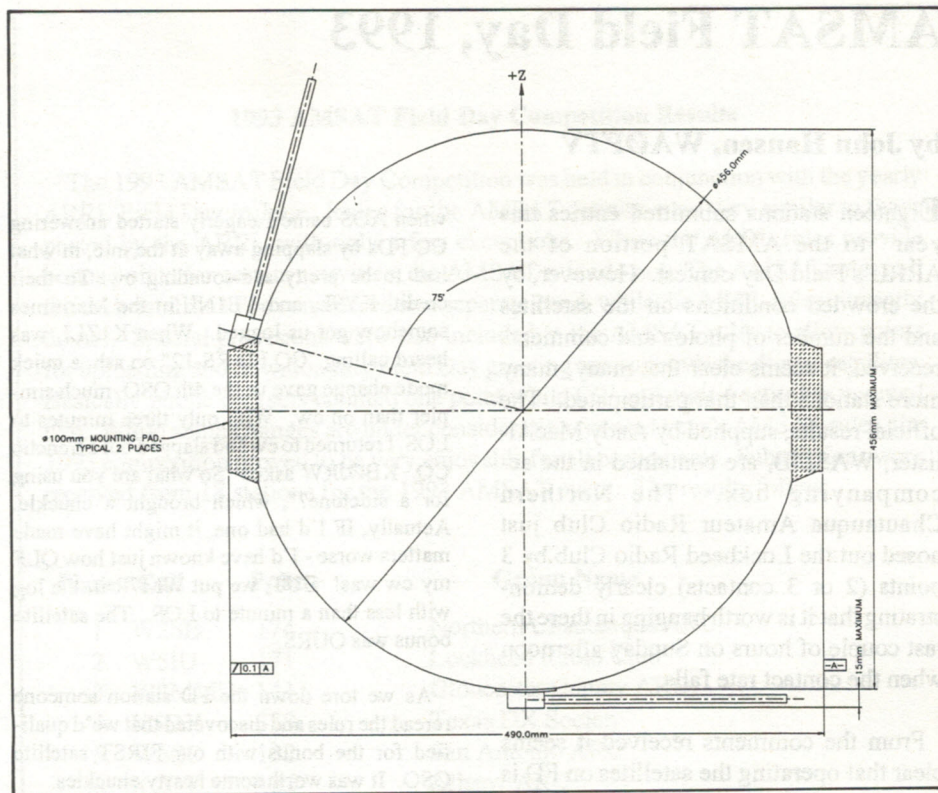


Fig.7, Propellant Tank

AMSAT Publications

Satellite Experimenters Handbook:

By: Marty Davidoff, K2UBC

A must for every Satellite enthusiast's bookshelf. Covers; history, fundamentals of station construction, tracking as well as advanced topics. \$23/25/30

PACSAT Beginner's Guide:

By Mike Crisler, N4IFD

Step by step instructions to becoming PACSAT-active. \$12/13/15

Beginners Guide to AO-13:

By Keith Bergland, WB5ZDP

Step by step instructions to becoming active on OSCAR 13. \$7/8/10

Beginners Guide to the RS Satellites:

By Gould Smith, WA4SXM

Step by step instructions to becoming active on the RS Satellites. \$7/8/10

Decoding Telemetry from the

Amateur Satellites:

By Gould Smith, WA4SXM

Describes the telemetry systems of each of the current Amateur Satellites - thru AO-21 and RS12/13. \$15/19/25

Weather Satellites Handbook:

By Ralph Taggart, WB8DOT

Describes the how-to's of receiving commercial weather satellite images on "ham accessible" equipment. Similar in scope to the Satellite Experimenter's Handbook. \$23/25/30/35

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AMSAT Field Day, 1993

by John Hansen, WAØPTV

Eighteen stations submitted entries this year to the AMSAT portion of the ARRL's Field Day contest. However, by the crowded conditions on the satellites and the number of photos and comments received, it seems clear that many, many more stations than that participated. The official results, supplied by Andy MacAllister, WA5ZIB, are contained in the accompanying box. The Northern Chautauqua Amateur Radio Club just nosed out the Lockheed Radio Club by 3 points (2 or 3 contacts) clearly demonstrating that it is worth hanging in there the last couple of hours on Sunday afternoon when the contact rate falls.

From the comments received it seems clear that operating the satellites on FD is an entirely different proposition than routine operation, even when the same equipment is used. More on that later. Here is a sampling of what the participants had to say:

Bruce Frahm, KØBJ (operating WØWOB):

As usual, we operated WØWOB as 2A in Field Day. With KFØMJ, NØSEG and KØBJ who'd worked packet with STS and MIR missions, and KØBJ active on RS-10 & RS-12 for 8 months, we decided it'd be an easy additional 100 points.

The heat of the battle during FD was a humbling experience. We had difficulty finding our signal on the RS-10 downlink in the QRM. With no luck answering stations due to fading, we called CQ on CW, and could hear a horde swooping in for the kill on the downlink. In fact, it became apparent there was so much FD activity that the bird's normally excellent age must be seizing up. Frantic searching on the Saturday evening passes and one Sunday morning yielded a solitary QSO with K7TR.

Sunday morning after my stint on 80/40 cw, it hit me that maybe RS-12 could supply the rest of the 5 QSOs we THOUGHT it took to give us the satellite bonus. One pass remained during FD, just an hour before the end of the contest. As I set up the FT757 and homebrew 15m beam for the pass, it dawned on me that our ONLY keyer was in use on 40cw, and I didn't relish the thought of picking out 4 SSB Qs uplinking with all the other sideband QRM in the 21.210-250 passband. What to do? Well, the mic PTT button keyed the rig in cw, so

when AOS came I eagerly started answering CQ FDs by slapping away at the mic, in what had to be pretty sad-sounding cw. To their credit, KY9L, and VE1NL in the Maritimes somehow got us logged. When K1ZLL was heard calling "CQ FD RS-12" on ssb, a quick mode change gave us the 4th QSO, much simpler than on cw. With only three minutes to LOS, I returned to cw and slapped out a frenetic CQ. KØJRW asked "So what are you using for a sidetone?", which brought a chuckle. Actually, if I'd had one, it might have made matters worse - I'd have known just how QLF my cw was! BUT, we put WM7R in the log with less than a minute to LOS. The satellite bonus was OURS.

As we tore down the FD station someone reread the rules and discovered that we'd qualified for the bonus with our FIRST satellite QSO. It was worth some hearty chuckles.

John Santillo, N2HMM, operating N2WM:

My station consisted of KLM 22C and 40cx antenna, Landwehr pre-amps, 80 watts on VHF and UHF and a Yaesu FT-736R. Even with this station I found it difficult at times to work the satellites. NO2G and I took a 6 foot TVRO dish and quickly homebrewed 2400 MHz feed-horn, a preamp and a mixer to attempt to work Arsene and AO-13 mode S, but unfortunately it failed. I think, by gentlemen's agreement, certain limits should be placed on satellite stations during Field Day (say, limiting uplink power to 50 watts or less) to better serve smaller stations.

Thomas M. Webb, WA9AFM operator for the Oklahoma City Autopatch Assn:

For the Oklahoma City Autopatch Association, Field Day '93 didn't start well. Heavy rains flooded the regular site. Luckily an alternate location was arranged.

There were two goals in mind for satellite operations during Field Day. First, achieve the bonus points and as many additional contacts as possible. Second, get the maximum number of folks exposed to amateur satellite operations. The first goal was accomplished within minutes of the start of FD with a contact through AO-21. Next, club members who weren't occupied were encouraged to stop by the satellite station. The "Mobile Space Communications Center" was dry, air conditioned, and had a comfy operating position.

Visitors were given a chance to work CW through AO-13 and listen to several of the

amateur satellites during passes over Oklahoma City. A demonstration of the simple antenna array (a Cushcraft AOP-1) and its Armstrong az-el system dispelled concerns that huge airplane-grabbing antennas were needed for satellites. Over the course of 24 hours several club members decided "this satellite stuff is neat!... How do I get started?"

The moral of this tale: don't let your Field Day satellite station be a mystery to your fellow club members... GET THEM INVOLVED!

Bruce Paige, KB5ARV, operating KK5W:

The KK5W satellite station was operated by Bruce Paige, KB5ARV, who received his call-sign last April (so much for satellite operation requiring years of experience! - ed.). Bruce designed the antenna support structure using PVC and wood doweling in the center for additional support. A slip ring was mounted around the vertical mast and guy wires attached. The antenna was rotated by hand and the elevation was also adjusted by hand by pulling on a string that was attached to the front and rear of the 2 meter antenna.

Vince Fiscus, KB7ADL, operating K7EFA:

Satellite operation during Field Day is fun. It is also a great way for us to inspire other hams to get involved in this exciting part of our hobby.

David Mein, N4MW, operating W4BS:

Using the same setup as last year, signals from AO-13 seemed weaker, so phone operation was not attempted. Also, competition from the 2 meter FD station was a problem. Otherwise, the timing of AO-13 was a great success.

Norman Osborne, VE3CJE operating VE3SOO:

Needless to say, Murphy was at work on Field Day. One of the antennas we constructed, a concentric mode B (RAYGUN) from a construction article in a back issue of 73 Magazine, worked perfectly on June 24, but not on Field Day.

Doyle Hodge, KB4ZXZ operating W4IZ:

Lots of folks came by to see what a satellite station was all about. We were also visited by

the local television stations which gave amateur radio as well as AMSAT great publicity. One of our most prized contacts was WD4FAB, Dick Jansson.

From the number of photos submitted with KLM beams and Yaseu az/el rotors it is clear that a significant number of participants simply take down their home stations and relocate them at the FD site. In previous years the W2SB group homebrewed a station to get the one contact needed for the ARRL bonus. This year we took down my home station to see what it was like to operate FD with a competitive setup. I had the same impression as many of those who wrote in. Do the satellites go deaf on Field Day? I operated this same station from a friend's driveway the day before FD and had nearly telephone quality signals from AO-13, but not on FD. One is tempted to chalk this all up to stations using excessive power on the uplink and I'm sure that is part of the problem. However, I didn't notice all that many stations with signals stronger than the beacon on AO-13 (no more than usual, that is).

Here are some tips for better Field Day operation for next year:

1. Get the best receiving system you possibly can. I can occasionally hear AO-13 clearly at home with a vertical antenna. This trick certainly will not work on FD.

2. Come prepared to operate at least several of the satellites. Given the signal levels involved, you can't realistically be guaranteed of making your one contact for the ARRL bonus on any given bird. This is particularly true of AO-21. Despite what the contest coordinator has written about operating this satellite with a handheld, a dual band mobile radio and a vertical will not get you into it when you are up against the competition on FD.

3. While running excessive power on the satellites is never justified, you can not reasonably expect to achieve the same performance you do at home with the same power level even if your equipment is exactly the same. We ran 50 watts on AO-13 into a KLM 40cx through almost no feedline, and this was perfectly adequate to make lots of contacts. It did not give us anything like the commanding signal that I expected, however. Next year I would expect to run the same uplink

1993 AMSAT Field Day Competition Results

The 1993 AMSAT Field Day Competition was held in conjunction with the yearly ARRL Field Day in June. Rules for the AMSAT activity were very similar to those posted by the ARRL with only a few exceptions. While the ARRL rules provide bonus points for certain activities, the AMSAT rules do not. The AMSAT rules call for each satellite to be considered as a separate band, while the ARRL rules currently do not. Special provisions were also included in the AMSAT rules to allow points for uploading and downloading Field Day greeting messages via the digital satellites. Basically phone contacts counted one point while CW and digital activities counted two. While some changes are under consideration for next year's AMSAT rules, the 1993 competition proved to be very enjoyable for all participants. Submissions were received from 18 stations for the 1993 AMSAT event. The results follow:

Place	Call	Points	Group Name
1.	W2SB	174	Northern Chautauqua ARC
2.	W5IU	171	Lockheed Radio Club
3.	W2MMD	141	Gloucester County ARC
4.	K5DX	139	Texas DX Society
5.	W5SC	132	San Antonio ARC
6.	K2CT	122	Albany ARC
7.	NX2Q	116	NX2Q Contest Group
8.	K1DW	110	The HAWG's
9.	W4IZ	102	N4ATM & Crew
10.	W4BS	96	Delta ARC and FedEx ARC
11.	W4AM	95	Chattanooga ARC
12.	N4NR	78	Shelby County ARC
13.	W8MRM	71	Motor City ARC
14.	K7EFA	67	KB7ADL & Crew
15.	W9KFB	62	Ron Cox
16.	N2WM	35	N2HMM & Crew
17.	KB9BNR	27	James Mayfield
18.	W1BD	6	Central Vermont ARC

power, but I will also be more realistic in my expectations for the station.

4. Practice. Each category of satellites requires somewhat different operating skills. If you attempt to operate a type of satellite you have never used before on FD, you may find yourself frustrated. For example, over the past year I had focused on the 9600 baud digital satellites to the exclusion of the 1200 baud PSK birds. Lack of recent experience severely hurt our station's performance on Oscar's 16 and 19. Similarly, if you haven't had some practice chasing your downlink signal on the RS birds, FD is a poor time to start. Your best bet is to get on each type of satellite for a number of hours over the

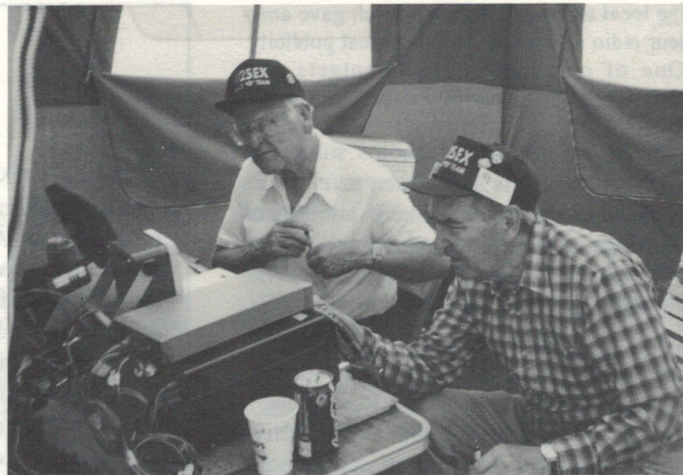
weeks preceding FD.

5. Almost any time Oscar 13 was up it was worth being on it. Even when the pointing angle was 40 to 50 degrees, contacts could be made on that satellite at a higher rate than on the LEO birds. When the pointing angle deteriorated a switch to CW allowed contacts to continue.

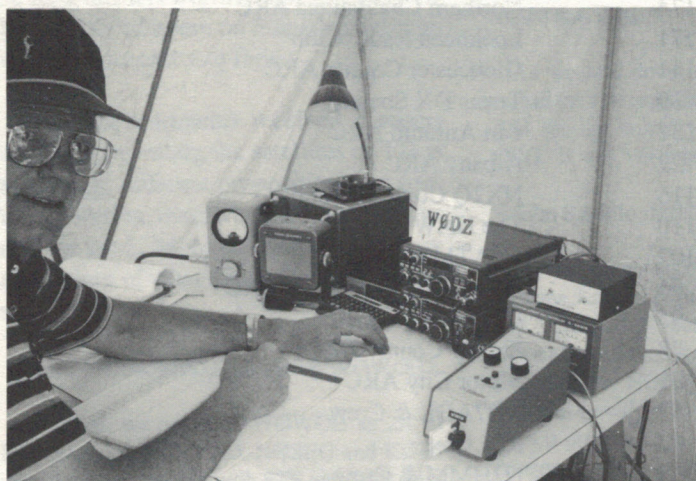
The number of official AMSAT entries were down a bit this year. This may be due to the fact that the administration of the contest changed hands rather late in the Spring and the contest announcement came out too late to be included in the *AMSAT Journal*. So mark your calendar for next year's FD and send in your entry!



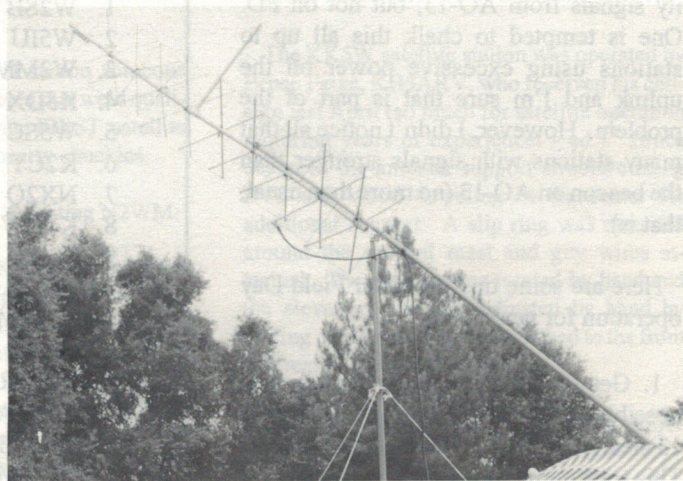
Ned Stearns, AA7A set up and operated the K7TR satellite station that netted 177 QSO's. (W1XT photo).



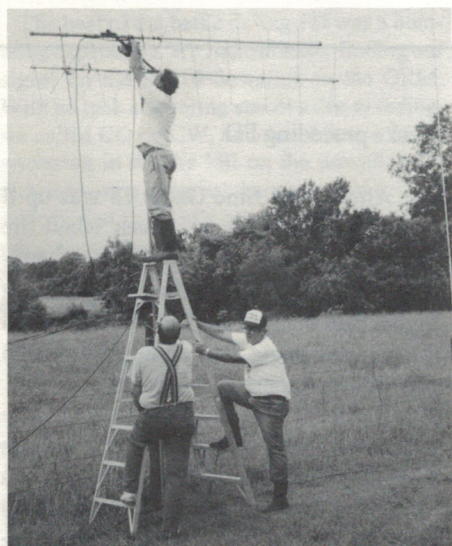
AA2AC, Vern and W2IZC, Syd work KO-23 for the W2SEX operation.



Does anyone really maintain a station this neat on Field Day?



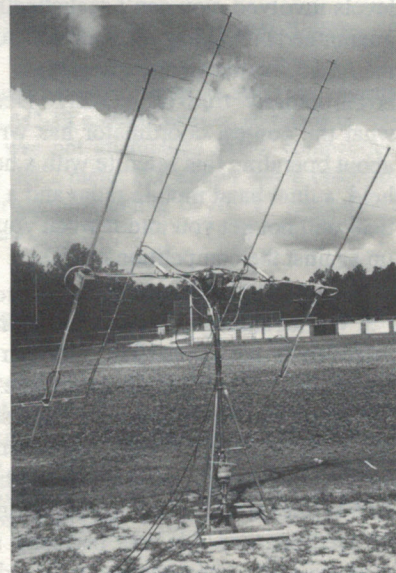
A 9 element quad was used for the 2 meter downlink at KD4GZK.



WA5TWT adjusts the antennas while N5ECP and N5XGW hold on at the K5DX operation near Kenney, Texas. (WA5ZIB photo)



Homebrew mode 70 cm helix was featured at KD4GZK.



The antenna array at W4IZ contributed greatly to their overall effort.

Groundstation Diagnosis

by Buzz Gorsky, WH6I

Editor's note: This column is a new feature for the AMSAT Journal. Each issue, we will take a set of questions related to establishing or improving an amateur satellite groundstation and ask someone who has been down this road before to answer them. While the authorship of this column will rotate, it is anticipated that the basic structure of the column will remain the same. If you would like to have your problem addressed in a future issue, please submit it to the Editor.

Dear Satellite Doctor:

I have been involved in packet radio for a number of years but have previously had no experience with satellite operation. Frankly, traditional analog satellites don't interest me very much, but I am very interested in getting involved with the digital satellites. My station equipment is currently very modest and includes the following:

1. A Kenwood TH27A two meter transceiver.
2. An 11 element 2 meter beam with rotator.
3. A PacComm Tiny 2 TNC.
4. An IBM compatible computer.

I have a number of questions:

1. I understand that there are a number of different kinds of digital satellites. Can you explain the differences between them and recommend one or two for me to start with? What types of information can I reasonably expect to download.
2. While I understand that this is going to cost me some money, I've got 2 kids in college and want to do it as cheaply as possible. However, I'm no technical guru so homebrewing any except the simplest equipment is not reasonable for me. Bearing this in mind, what types of equipment should I be looking at. Is it possible to get a foothold now with, say, less than a thousand dollars, and expand later?
3. What sources of information are available that might help me get started? Thanks in advance, (signed)

A Packeteer and AMSAT Member.

The digital satellites are not the traditional way to get into amateur satellites, but it is actually not more difficult to begin on the "digs" than on the analog birds. The digital satellites are first and foremost orbiting bulletin boards, but they contain vastly more information than simply personal messages and bulletins. They also have files of software, digitized pictures (some taken by the satellites themselves), digitized voice and just about anything else you can think of that can be digitized in a few tens or hundreds of kilobytes.

There are currently two basic kinds of digital satellites in orbit, and while much of the equipment is usable on either type, it is probably wise to make a decision about which type to pursue first. AO-16 (Pacsat), LO-19 (Lusat), WO-18 (Webersat) and FO-20 all run at 1200 baud. They require a two meter FM uplink and a 70 cm SSB downlink. While these satellites are 1200 baud, your AFSK Pacomm Tiny 2 will not demodulate the phase shift keying (PSK) signal from these satellites. An outboard PSK modem will be required. PacComm manufactures one of these that can be wedded to your Tiny 2 (about \$250) or the Tucson Amateur Packet Radio (TAPR) group has a kit available for just over \$100. The TAPR kit is no Heathkit, however, and it should only be attempted by relatively experienced builders. Connecting a PSK modem to your rigs would be similar to the connections that you use for terrestrial packet. If the rigs have connections intended for use with TNCs, then these should be used instead of the microphone and headphone jacks. The connections intended for digital use will generally modify the audio to and from the modem less than will the circuits intended for voice use.

Since the satellites move with respect to the earth, the apparent frequency of the received signal changes. While it is not

essential to adapt your 2 meter uplink frequency for Doppler shift, it is necessary to track the Doppler on the downlink. PSK modems generally do this by providing outputs from the modem that activate the up and down buttons on the microphone jack of the radio to keep the SSB signal properly tuned. This process works quite well and occurs automatically.

UO-22 (UoSat 22), and KO-23 (Kitsat-A) as well as the recently launched Kitsat-B operate at 9600 baud. They require 2 meter FM on the uplink and 70 cm FM on the downlink. Your Tiny 2 would also serve as the basis for a 9600 baud groundstation, but you would need to add a 9600 baud modem. PacComm offers one that is designed to be mated to your Tiny 2 for about \$110. MFJ, DRSI, and AEA also make TNC/9600 baud modem combinations. Both L.L. Grace and AEA make digital signal processing units that will handle all of these modes, but these units are probably beyond your budget. While the data on the 9600 baud satellites moves at eight times the speed as the 1200 baud satellites, there are some disadvantages of going this route. With the exception of a crystal-controlled unit from Kantronics, there are currently no amateur type radios available that will do 9600 baud right out of the box. The modifications are often fairly simple (involving knowing where to hook up transmit and receive audio wires), but you will have to dig into the radio to find where they go. While I have seen a modification for the TH 77 handheld to do 9600 baud, I know of no published mod for the TH 27 and in any case making modifications to the inside of handheld radios is a dicey business.

Thus you must weigh the trade-off of having to buy radios for both bands and obtaining higher data rates against buying a more expensive modem, but only having to buy a radio for one band. Given that the

handheld probably does not generate enough power to reliably work the birds, you will probably need to acquire an amplifier even if you use your 2 meter radio for the uplink. One last advantage of going the 9600 baud route is that PSK modems are useful only for operating PSK satellites. 9600 baud modems, on the other hand, may have terrestrial applications as more and more BBS's open 9600 baud user ports.

Assuming you opt for the PSK birds, you have some components that will work on the satellites, and there are some that you must acquire. A PSK satellite groundstation must be able to send an FM signal on two meters and receive an SSB signal on 70 cm (440 MHz). The station needs a modem capable of working with pacsat's modulation scheme, a TNC, and a computer. You have a two meter FM transmitter, antenna, and rotor (we'll return to antennas in a moment), so you need a multi-mode rig for 70 cm. You cannot use a transverter to work with your 2 meter equipment since digital satellite operation is duplex--that is you send and receive at the same time. However if you happen to have an HF transceiver, you could use a receive converter with that rig.

The other option would be to obtain an all-mode 70 cm rig. Don't overlook the used equipment market. Older multimode radios are now coming on the market for both 2 meters and 70 cm at very reasonable prices.

Besides the two rigs, you obviously need antennas. There are essentially two major choices of antennas (the considerations are the same for both bands). You can use beam antennas or non-directional ones. Beams increase your radiated power and improve received signal strength, but they must be pointed correctly. Since the satellite moves across the sky changing both its azimuth and elevation above the horizon, you need two rotors, an azimuth rotor and an elevation rotor to tip the antennas up above the horizontal. It is possible to avoid the elevation rotor and mount the antennas at about a 25 to 45 degree elevation. If the antennas do not have too small a beamwidth, then this will work for most mid-elevation passes. You could use your 11 element 2 meter beam and a similarly small 70 cm beam in this fashion. This option would be a bit

cheaper than purchasing two beams, but you would miss high elevation and low elevation portions of orbits. Furthermore antennas intended specifically for satellite use are "circularly polarized" rather than vertically or horizontally polarized.

A common way of achieving circularity is to mount two beams on the same boom with the beams oriented ninety degrees to each other. With proper feed-line arrangements this will produce a circularly polarized signal. A CP signal can have either Left or Right sense. Some antennas are built one way or the other to maximize a particular satellite, while others have a circularity switcher which permits selection of left or right hand polarization.

If you choose a non-directional antenna arrangement, you do not need rotors and you do not need to point the antennas during the pass. However, you will be competing for access to the satellite with stations that are using Oscar 13 class stations. If you are in an area of the world with a large amateur population, you will probably find the performance to be ultimately disappointing without directional antennas. Omni's may be a good way to get started though, particularly if you can inexpensively homebrew the antennas. Since satellite transmitters are relatively low in power, and since there is significant path loss diminishing the signal, many amateurs find it useful to employ a receive pre-amplifier. This will probably be essential if you opt for the omnidirectional antenna approach, though for the low earth orbiting digital birds this would likely not be necessary if you use a CP beam.

One other antenna related item is important. Since the received signal is often so weak, it is important to minimize signal loss from antenna to rig as much as possible. Therefore you should use N connectors and a low loss coax such as 9913 or even hard-line. If the distance from your shack to your antennas is quite short, you might find that a good grade of RG8 is sufficient.

With all of that hardware assembled, there are a few software things to consider. You will probably want to obtain one of the commonly used satellite tracking programs. QuikTrak and InstantTrack are available from AMSAT and will take care of your needs. InstantTrack comes with

some utilities which are very handy for automating many aspects of a satellite station. Both will provide you with the times when the satellites are above your horizon as well as azimuth and elevation angles.

You must also use special software to communicate with the BBS aboard Pacsat. (You can use a normal packet program to connect to Fuji Oscar 20 by typing "c8j1jbs".) These programs come in a collection which provides utilities to process files you wish to upload to the satellite as well as files received from the satellite BBS. In addition a program called PG is used to upload files and one called PB is used to obtain a directory of what is on the BBS and download data from the satellite. This suite of programs is also available from AMSAT. There are many other programs that you might become interested in as you become more familiar with satellite operation, but these will get you started. With your Pacsat station you can also work Lusat (though currently you would need a different version of PB and PG). You could also use PB to receive packet data from Webersat which provides image files (pictures of small areas of the earth) as well as data from on-board experiments.

If you decide to begin with the 9600 baud satellites you will find your software needs will be virtually identical to those for the 1200 baud birds. You will need to acquire radios for both the uplink and downlink and be certain that they can be modified to run 9600 baud. On the other hand, you will not need multimode radios since the uplink and downlink are both FM. The receive bandwidth required by the satellites seems to be somewhat wider than that required for 9600 baud terrestrial work, so make sure that you use a 70 cm radio with a bandwidth of at least 15 KHz. A lot of data can accumulate in a short time at 9600 baud... it is possible to receive a half a megabyte of information from one of these satellites in a single pass, so if you become active on these birds, you might want to consider a bigger hard drive!

Additional information on packet satellite operation can be obtained from (surprise!) AMSAT. A Pacsat Beginner's Guide is available which contains detailed information on setting up a digital groundstation and also includes the PB/PG software you will need to access the birds.

Heard on the Downlink

by John Hansen, WAØPTV

Changes at the Journal

Over the years this publication has gone through a number of incarnations as the search continued to produce a publication that best met the needs of the membership. It has been a bi-monthly journal now for a number of years, but even so the emphasis has changed both with changing times and changing staff. And so it goes.

Most recently I have been entrusted with the responsibility for the Journal and that will involve some shift of focus. Professional journals are generally compilations of technical papers that have been formally "refereed" by anonymous reviewers. The *Amsat Journal* has always made an effort to attract many papers of this type. However, the Journal is also the principal means that AMSAT-NA has of distributing information to its members and in addition one of the main written forums for members to communicate with each other. Thus, there is a strong justification for incorporating a wide range of information, from news, to operating tips, to information for beginners. It is with this in mind that I have made a number of changes in the Journal, including this column, Notes from the Field, and Groundstation Diagnosis. Fortunately the thirty-two pages that appear in the Journal each issue provide a lot of room for diversity. I expect to continue to offer the kind of top notch technical articles that you have seen here in the past. It probably sounds trite, but this publication really does belong to the membership. Let me know what you want to see and we'll try to provide it.

This issue we are fortunate to have a new member of the *Journal* editorial board. Buzz Gorsky, WH6I has his finger on the pulse of AMSAT in the Pacific (as well as other pulses... he's a physician). He has graciously volunteered to help produce this Journal. Thanks Buzz.

Michaelangelo Spotted at WAØPTV

A week or so after the last issue of the *Amsat Journal* was mailed I discovered

that the Michaelangelo virus had infected my computer system. I thought it best to inform you of this because a significant number of people have sent me disks asking for software mentioned in this column. If you are one of those folks and you received software from me before the second week in September you should scan your disk to see if it has become infected.

There are a number of clues that indicate generally where the virus came from. As it turns out the computer in my office was not infected. Furthermore, I have had reports now from many folks who downloaded software that I had uploaded to KO-23 and none of them report being infected. I've concluded from this that this virus spreads generally on disks and not in executable files. I suspect that what happened is that someone unknowingly sent a formatted floppy to me that contained the virus. As of the middle of September all formatted blank disks that I receive will be scanned for viruses before anything is put on them.

If you are planning to use McAfee's shareware virus scanner "SCAN.EXE" to detect this virus, make sure you obtain a version more recent than V100. When I scanned for the virus with version 100 of SCAN, it reported that the computer was infected with the stoned virus. Since the diagnosis was incorrect, cleaning the disk with McAfee's CLEAN would not work. I finally positively identified the virus with version 106 of SCAN. If you need a copy of SCAN and CLEAN, send me the usual formatted disk with a return mailer and postage and I'll see that you get it.

More on PB/PG for the MacIntosh

Last issue I discussed a communication from Ron Cox, W9KFB concerning the success he had experienced getting the digital satellite groundstation program PB to run on his MacIntosh. He had had far less success with PG since it requires hardware support of the DCD line. After the issue appeared I received communication from Ronald Parsons, W5RKN. He has discussed this with Insignia Solutions, the manufacturer of SoftPC and was told at the

time it was not possible. He did suggest, however, that if Apple's recommended "hardware handshake cable" were used, SoftPC could test for DCD and thereby allow Mac users to run programs like PG. He suggested that if enough folks mentioned this to Insignia, perhaps they would do something about it. In the meantime, if you are using an alternative to PG on the Mac, please drop me a note. Inquiring minds want to know.

Take it Easy on Mode S

I had heard (on the downlink!) something about the mode S transponder being a "hard-limiting" transponder and that this could cause some problems when individuals used too much power on the uplink, and that this was a more serious problem on mode S than mode B. I asked Steve Todd, K2IYQ, to explain it to me. He sent the following:

Mode S on AO-13 today is working quite well. And low power is quite acceptable, especially when the satellite is close to you. The mode S receiver operates much the same as an FM receiver, i.e. the stronger signal captures the channel. Now this has the effect of causing all other signals in the passband to be reduced in apparent strength. Since we are using either SSB or CW, the signal reduction seems to vary at a syllabic or cw rate. Thus if I am working a station that is not too strong to begin with, it is possible for him to completely disappear if a VERY strong station has captured the receiver. This is the perceived effect of "hard limiting" in the Mode S receiver.

From this comes the STRONG recommendation to use only enough power on the uplink to be heard on the downlink. Most of the rigs out there today have the capability to reduce the transmitter power. However, some operators just crank up the wick for max smoke.

Fiberglass Rods

From Ron Long, W8GUS, comes what may be the last word on nonconductive

(continued on page 26)

AMSAT News

Phase 3-D Help Wanted

The AMSAT Phase 3-D team is looking for some assistance with specific tasks in conjunction with the development of this new spacecraft. Some of these needs are immediate and some are longer term. If you can assist in any of the following ways, please contact Dick Jansson AMSAT-NA Vice President, Engineering at any of the addresses listed below.

1. An additional machinist with access to a numerically controlled (NC) lathe and who can also produce modest quantities (50+) of small aluminium inserts for honeycomb panels. Inserts will be used in manufacturing P3-D's solar arrays. Need is ASAP. (and urgent)

2. Someone to secure air conditioned warehouse space (1200-1500 sq ft) in the Orlando, Florida area for spacecraft integration efforts. Need 5/94 (May 94) to 9/95 (Sept 95).

3. Cabinetmaker to build shipping cases for solar panels. This need is also ASAP.

4. Facility Manager for the Spacecraft Integration Facility in the Orlando, Florida area. Need 3/94 to 10/95.

5. Carpenter to build "clean room" facility (wood and plastic and plastic sheeting "tent" with filtered blower system) in the Spacecraft Integration Facility, Orlando, Florida area. Need 5/94 to 9/95.

6. Electrical Engineer to perform wiring and cabling detail design work for wiring the P3-D flight model spaceframe. Need 12/93 thru 10/95.

7. Wiring and Cabling Technician (with spacecraft qualifications) to help wire the flight model P3-D spacecraft. Orlando, Florida area. Need 7/94 to 10/95.

8. "Hands-on" workers to help with Spacecraft integration. Orlando Florida area 5/95 to 1/96.

Anyone with these capabilities and who would like to volunteer should contact Dick Jansson directly via E-mail at

wd4fab@amsat.org, or by fax at 407-644-9782.

The AMSAT BBS Network

The AMSAT BBS Network now includes the following BBS's.

CompuServe's HAMNET
Sysop: Scott Loftness (W3VS)
760703.407@CompuServe.COM

Western Pacific BBS
Phone #: 415-453-2854
Up to 14,400bps V.32bis
Sysop: Daniel C. Dufficy (KH8AF)
kh8af@crl.com

The ARRL BBS
Phone #: 203-666-0578
Sysop: Luck Hurder (KY1T)
lhurder@arrl.org



How it all began... Dick Esneault, W4IJC, a member of the original Project Oscar team, holds one of the very early engineering models of amateur radio's first satellite, OSCAR 1, at the recent 1993 ARRL National Convention in Huntsville, Alabama (AMSAT-NA Photo).

California Amateur Radio Emergency Services (CARES) BBS
Phone #: 916-323-4826
Sacramento, CA
Sysop: Gorden Fuller (WB6OVH)
gfuller@sfovmici.vnet.ibm.com

AMSAT Sats & Stats BBS
Phone #: 201-261-2780
New Jersey
Up to 14,400bps
Sysop: Mel Roman (KA2UPD)
70712.1050@CompuServe.COM

HAMLINK
Phone #: 612-426-0000
Minnesota
Up to 9600bps
Sysop: John Desmond (K0TG)
k0tg@amsat.org

OCA/AMSAT BBS
Phone #: 714-738-4331
Fullerton, CA
Up to 14,400bps V.32bis
Sysop: John Wisniewski (N6DBF)
n6dbf@amsat.org
CompuServe: 70233,75

If you run a BBS and would like to join The AMSAT BBS Network, John Wisniewski, the AMSAT-NA BBS coordinator, would like to hear from you. Please provide the following information:

The name of your BBS
Phone number
Location (city, state)
Baud rate
Sysop's name and Internet and/or CompuServe address.
General description of the files you post.

John can be contacted at:
INTERNET: n6dbf@amsat.org
CompuServe: 70233,75



Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	AO-21	RS-12/13
Catalog Number	14129	14781	18129	19216	20480	21087	21089
Epoch Time	93279.33702867	93287.01910323	93286.63524979	93281.01224299	93286.05864589	93286.04684787	93285.72497418
Element Set	82	602	802	695	601	354	602
Inclination	27.1481	97.8038	82.9272	57.8884	99.0206	82.9463	82.9243
RA of Node	2.4799	308.1221	151.0843	290.6961	119.8565	325.6114	194.9512
Eccentricity	0.6019419	0.0011698	0.0011771	0.7215384	0.0540673	0.0036668	0.0030810
Arg of Perigee	119.8710	343.7711	355.8415	325.7101	179.4597	54.2687	77.1277
Mean Anomaly	312.5993	16.3119	4.2641	4.0040	180.7200	306.1872	283.3318
Mean Motion	2.05881755	14.69066684	13.72323405	2.09725266	12.83221389	13.74525633	13.74028313
Decay Rate	-.00000081	.00000333	-.00000137	-.00000111	-.00000014	.00000046	.00000142
Epoch Rev	7754	51416	31609	4072	17243	13563	13466
Satellite	UO-14	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23
Catalog Number	20437	20439	20440	20441	20442	21575	22077
Epoch Time	93287.74004034	93285.21602800	93287.78324469	93287.68449871	93285.71973157	93285.23553413	93278.76031854
Element Set	902	702	702	703	702	402	160
Inclination	98.6074	98.6146	98.6149	98.6151	98.6154	98.4589	66.0854
RA of Node	10.6604	9.1530	11.9369	11.8577	10.1138	359.4059	92.6845
Eccentricity	0.0010837	0.0011065	0.0011286	0.0011859	0.0012034	0.0007231	0.0002474
Arg of Perigee	188.2101	196.1718	187.9570	188.4687	194.7920	316.6360	358.7953
Mean Anomaly	171.8903	163.9127	172.1434	171.6297	165.2908	43.4257	1.3056
Mean Motion	14.29796548	14.29854129	14.29991244	14.29969421	14.30060813	14.36856146	12.86280742
Decay Rate	.00000072	.00000109	.00000081	.00000047	.00000081	.00000131	.00000000
Epoch Rev	19451	19416	19454	19453	19426	11747	5405
Satellite	KO-25	IO-26	AO-27	MIR	POSAT	MET-2/17	MET-3/2
Catalog Number	22830	22826	22825	16609	22829	18820	19336
Epoch Time	93286.24408072	93285.89749859	93285.75852196	93287.91659936	93286.45464408	93285.03200310	93288.07651144
Element Set	203	203	202	513	203	201	202
Inclination	98.5818	98.6800	98.6768	51.6198	98.6757	82.5394	82.5421
RA of Node	359.0811	358.8662	358.7223	337.9204	359.4183	105.9887	137.1408
Eccentricity	0.0011764	0.0008357	0.0007582	0.0006216	0.0010287	0.0016962	0.0017195
Arg of Perigee	176.3255	209.4671	207.9609	305.1714	192.1840	153.8192	152.6559
Mean Anomaly	183.8015	150.6040	152.1156	54.9308	167.9104	206.3830	207.5504
Mean Motion	14.28008897	14.27683559	14.27584304	15.58279881	14.27974280	13.84694680	13.16961632
Decay Rate	.00000388	-.00000738	.00000108	.00012841	-.00000675	.00000033	.00000043
Epoch Rev	245	240	237	43779	248	28801	25099
Satellite	MET-2/18	MET-3/3	MET-2/19	MET-2/20	MET-3/4	MET-3/5	MET-2/21
Catalog Number	19851	20305	20670	20826	21232	21655	22782
Epoch Time	93285.09728344	93287.40151059	93284.85954447	93286.20117621	93287.22970807	93285.20994771	93286.73557409
Element Set	202	903	702	702	603	602	202
Inclination	82.5208	82.5504	82.5464	82.5269	82.5432	82.5547	82.5482
RA of Node	341.7155	80.7645	45.7127	342.4946	343.4821	291.8713	41.7313
Eccentricity	0.0013817	0.0016082	0.0017111	0.0014066	0.0014836	0.0014636	0.0022204
Arg of Perigee	197.6615	174.5084	120.8594	25.5065	82.2352	96.3433	192.7322
Mean Anomaly	162.3951	185.6564	239.4252	334.6787	278.0453	263.9392	167.3281
Mean Motion	13.84346436	13.16023037	13.84178556	13.83560871	13.16455196	13.16825416	13.82987190
Decay Rate	.00000100	.00000043	.00000096	.00000096	.00000043	.00000043	.00000094
Epoch Rev	23336	19078	16626	15360	11899	10382	602

Spacecraft Engineering Bibliography

by Walter Daniel KE3HP

While there are books that describe amateur spacecraft in general terms, some amateur satellite operators are interested in detailed references regarding spacecraft design. For the first 30 years of the space age, few texts in this field were written. In recent years, many well-written and highly useful texts about spacecraft design have been published. This article reviews several currently available books that provide overviews of spacecraft missions and satellite engineering.

Astrodynamics

Perhaps the most important aspect of a space mission is the orbit. A widely-read text on the subject is *Fundamentals of Astrodynamics* by Bate, Mueller, and White (Dover Publications, New York, 1971). This book was written by instructors at the United States Air Force Academy. Topics covered include two-body orbital mechanics, orbital maneuvers, orbit determination, and interplanetary trajectories. Part of the popularity of this paperback book is the low price (less than \$10).

Mission Analysis

Designing a space mission is a multidisciplinary process. As recently as 1990, no reference existed that covered material from such diverse disciplines (subsystem design, orbits, instruments, launch vehicles, etc.), so a group of engineers prepared a book with funding in part from U.S. military space organizations. The result, *Space Mission Analysis and Design* (1991), was edited by James Wertz and Wiley Larson and published by Kluwer Academic Publishers, Dordrecht, The Netherlands. A second edition was published in 1992. Chapters and sections were contributed by numerous authors in industry, academia, government, and the military. The goal of the book was to provide all the material needed to perform a preliminary space mission design. This text is available in both hardcover and lower-cost softcover.

Spacecraft Engineering

Some recent books focus on design of the spacecraft itself rather than the entire

mission. These references are especially useful for engineers working on individual subsystems, but engineers at the system level can also benefit from the detailed information about spacecraft hardware.

Design of Geosynchronous Spacecraft (Prentice-Hall, Englewood Cliffs, NJ, 1986) was written by Dr. Brij Agrawal when he was employed by INTELSAT. The emphasis of the book is on geosynchronous communications satellites of the type that INTELSAT uses to provide global telecommunications services. There are chapters on spacecraft configuration, orbit dynamics, attitude dynamics and control, structures, thermal control, power, and communications.

Satellite Technology and Its Applications (McGraw-Hill, second edition 1991) by P. R. K. Chetty of Fairchild Space is a more general reference and includes much detail about actual spacecraft hardware. In addition to the chapters on subsystems, there are two chapters on spacecraft applications.

Space Vehicle Design (American Institute of Aeronautics and Astronautics, Washington, DC, 1991) by Michael Griffin and James French is intended as a textbook for senior-level courses in space systems engineering. The book covers subsystems using a tutorial approach. Dr. Griffin is currently the Chief Engineer of NASA; Mr. French is retired from the NASA Jet Propulsion Laboratory and is an aerospace consultant.

Spacecraft Descriptions

Descriptions of spacecraft are available from a somewhat unexpected source: large-format or "coffee-table" books. Each satellite photograph or drawing contains a wealth of data regarding size, shape, and layout; accompanying text gives information on missions and sensors.

Aviation and space author Bill Yenne has written or edited several books about spacecraft and space science for Exeter Books. *The Encyclopedia of US Spacecraft* (1985) lists American satellites in

alphabetical order and includes information such as satellite weight and size. *The Pictorial History of World Spacecraft* (1988) shows space technology development in a chronological fashion beginning with the launch of Sputnik 1 by the Soviet Union in 1957. *Interplanetary Spacecraft* (1988) concentrates on missions launched to other planets; the book includes an example design for a Pluto flyby mission.

The Illustrated Encyclopedia of Space Technology (Revised Edition, 1989) by Kenneth Gatland (Crown Publishers, Inc., New York) is a compendium of knowledge about all aspects of space including satellite engineering. Another book from Crown Publishers is *The Complete Encyclopedia of Space Satellites* (USA edition 1986) by Giovanni Caprara. Caprara's work includes descriptions and line drawings of virtually every satellite launched between 1957 and 1986.

Sources

A college or university bookstore is a good source for engineering texts. While a particular title may not be in stock, the bookstore should have a special order department that can acquire any book in print. Some of these establishments may also have general interest books.

Finding space technology texts is often difficult even for professionals working in the field. To address this problem, a company named Microcosm began a mail-order service known as Discount Astronautics Books (DAB). The 20-page DAB catalog contains short descriptions of numerous technical and reference books. To request a copy of the catalog, contact Microcosm, 2601 Airport Dr., Suite 230, Torrance, CA 90505. The phone number is 310/539-9444.

Finding the "coffee-table" books may take a bit of effort. If a book is in print, most bookstores should be able to order it. If the book is out of print, searching retail stores may be the only option. For example, *Interplanetary Spacecraft* has appeared in more than one discount book retailer even though the title may still be in print.

Expanded Listing

The following text is an extended listing of references in or related to spacecraft engineering. Due to the length of the list, no descriptions are included. These books are sorted by topic such as "astrodynamics" or by category such as "magazines."

AMATEUR RADIO

The ARRL Handbook for Radio Amateurs; ARRL; annual

The ARRL Operating Manual; 4th edition; ARRL; 1991

ARRL Satellite Anthology; 2nd edition; ARRL; 1990

Beginners Guide to AO-13; Bergland; AMSAT-NA; 1989

Beginners Guide to the RS Satellites; Smith; AMSAT-NA; 1992

Decoding Telemetry from the Amateur Satellites; Smith; AMSAT-NA; 1991

Pacsat Beginners Guide; Crisler; AMSAT-NA; 1991

The Satellite Experimenters Handbook; 2nd edition; ARRL; 1990

ASTRODYNAMICS

An Introduction to the Mathematics and Methods of Astrodynamics; Battin; AIAA; 1987

Fundamentals of Astrodynamics; Bate, Mueller, and White; Dover; 1969

Spaceflight Dynamics; Wiesel; McGraw-Hill; 1989

Spacecraft Mission Design; Brown; AIAA; 1992

ASTRONOMY

The Astronomical Almanac; U.S. Government Printing Office; published yearly

Astronomy: the Cosmic Perspective; 2nd edition; Zeilik and Gaustad; Wiley; 1990

Explanatory Supplement to the Astronomical Almanac; University Science Books; 1992

ATTITUDE DYNAMICS AND CONTROL

Introductory Attitude Dynamics; Rimrott; Springer-Verlag; 1989

Modern Spacecraft Dynamics and Control; Kaplan; Wiley; 1976

Spacecraft Attitude Determination and Control; Wertz; D. Reidel; 1978

Spacecraft Attitude Dynamics; Hughes; Wiley; 1986

Spacecraft Attitude Dynamics and Control; Chobotov; Krieger Publishing Company; 1991

Spacecraft Dynamics; Kane, Likins, and Levinson; McGraw-Hill; 1983

COMMUNICATIONS

Communications Satellite Systems; Martin; Prentice-Hall; 1978

Laser Satellite Communications; Katzman; Prentice-Hall; 1987

Satellite Communication Systems Engineering; Pritchard and Sciulli; Prentice-Hall; 1986

Satellite Communications; Pratt and Bostian; Wiley; 1986

Satellite Communications; Roddy; Prentice-Hall; 1989

Satellite Communications Systems; Maral and Bousquet; Wiley; 1986

DESIGN

AIAA Aerospace Design Engineers Guide; 3rd edition; AIAA; 1993

Design of Geosynchronous Spacecraft; Agrawal; Prentice-Hall; 1986

The International Ultraviolet Explorer Case Study in Spacecraft Design; Freeman and Longanecker; AIAA; 1979

An Introduction to Mission Design for Geostationary Satellites; Pocha; D. Reidel; 1987

Marks' Standard Handbook for Mech. Engineers; Avallone and Baumeister; McGraw-Hill; 1987

Pioneer Venus Case Study in Spacecraft Design; Brodsky; AIAA; 1979

Satellite Technology and its Applications; 2nd edition; Chetty; McGraw-Hill; 1991

Space Mission Analysis and Design; 2nd edition; Wertz and Larson; Microcosm; 1992

Space Vehicle Design; French and Griffin; AIAA; 1990

Spacecraft Systems Engineering; Fortescue and Stark; Wiley; 1991

GENERAL

Artificial Space Debris; Johnson and McKnight; Krieger Publishing Company; 1987

Astronomy and Astronautics: Guide to Books and Periodicals; Lusi; Facts on File; 1986

Atlas of the Solar System; Yenne; Exeter; 1987

CRC Handbook of Space Technology: Status and Projections; Hord; CRC Press; 1985

The Dictionary of Space Technology; Angelo; Facts on File; 1982

The Grand Tour: a Traveler's Guide to the Solar System; Miller and Hartmann; Workman; 1981

The Illustrated Encyclopedia of Space Technology; Gatland; Crown Publishers; 1984

Introduction to Flight; Anderson; McGraw-Hill; 1989

Introduction to Space: the Science of Spaceflight; Damon; Krieger Publishing Company; 1989

Introduction to the Space Environment; Tascione; Krieger Publishing Company; 1988

Remote Sensing: Methods and Applications; Hord; Wiley; 1986

Satellite Astronomy: The Principles and Practice of Astronomy from Space; Davies; Wiley; 1988

Space Handbook; Air University Press (US Government Printing Office); 1985

Space: the Next Twenty-Five Years; McDonough; Wiley; 1989

TECHNICAL JOURNALS

Acta Astronautica; Pergamon Press

Journal of Guidance, Control, and Dynamics; American Institute for Aeronautics and Astronautics

Journal of Spacecraft and Rockets; American Institute of Aeronautics and Astronautics

Journal of the Astronautical Sciences; American Astronautical Society

Journal of the British Interplanetary Society; British Interplanetary Society

MAGAZINES

Aerospace America; American Institute for Aeronautics and Astronautics

Aviation Week and Space Technology; McGraw-Hill

NASA Activities; US Government Printing Office

Space News; Times Journal Company

MISSION STUDIES

America at the Threshold; Synthesis Group; US Government Printing Office; 1991

CRC Handbook of NASA Future Missions and Payloads; Hord; CRC Press; 1987

Leadership and America's Future in Space; Ride; US Government Printing Office; 1987

Pioneering the Space Frontier; National Commission on Space; Bantam Books; 1986

Planetary Exploration through Year 2000 (5 volumes: *Executive Summary, Core Program, Augmented Program, Mission Operations, Scientific Rationale*); *Solar System Exploration Committee*; US Government Printing Office; 1983-1989

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2. Stations wanting to use the Bureau; arrange your cards ALPHABETICALLY by call sign. Stateside cards are free. However there is a charge of 5 cents per card for all stations outside US Postal districts.
4. Always keep the Bureau informed of any changes in your address or call sign. If you have worked stations using more than one call sign, you should send envelopes for both call signs.
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6. QSL cards that are received at the Bureau when there are no envelopes on file will be held and the Bureau will make an attempt to notify the user that he/she has cards on file. If no envelopes are sent to the Bureau within a period of 6 months, the cards will be destroyed!
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8. Any questions about the Bureau should be sent with an SASE to the QSL Bureau Office. ■

Perry Yantis, WB8OTH
AMSAT QSL Bureau Manager

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P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
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SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	<1.2	17	-20	Bipolar	\$79.95
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An Amateur Satellite Operation Upgrade Path

by G. Gould Smith, WA4SXM

The summer of 1992 found thirteen active amateur satellites plus the Mir space station orbiting the earth. These satellites operate using many different modes and modulation methods. With so many choices available it can be somewhat overwhelming to determine how and where to begin or where to go next. AMSAT publishes guides to most of these satellites, but some are so new and things change so rapidly that it is often difficult to stay current. One of the most common questions I am asked is 'What does it take to get on the satellites?'. Since most newcomers don't know about the multitude of modes in use, they assume it requires a single setup, like getting on CW, packet, SSTV or RTTY.

Satellite operation is experimental by nature. Those volunteers who conceive, design, build and command the amateur satellites are interested in a challenging undertaking. So each generation of amateur satellite is different and more experimental. The documentation concerning the newer satellites always seems to be slow to follow. I suspect this is because it is not the most exciting thing to do, and the designers are into another interesting challenge. Other VOLUNTEERS must step forward and fill in the holes that are found. Give back some of the enjoyment you have gotten from satellite operation. Satellite operation is not 'turnkey', it requires the participants to ask questions and track down information. AMSAT-NA is a volunteer organization, as such there is no 'THEY' to provide all of the answers for you. The AMSAT Area Coordinators are a network of volunteers willing to provide assistance and guidance to anyone interested in amateur satellite operation. They are the best place to start in your information quest. AMSAT nets and the CompuServe Amateur Satellite forum in HAMNET are also good sources.

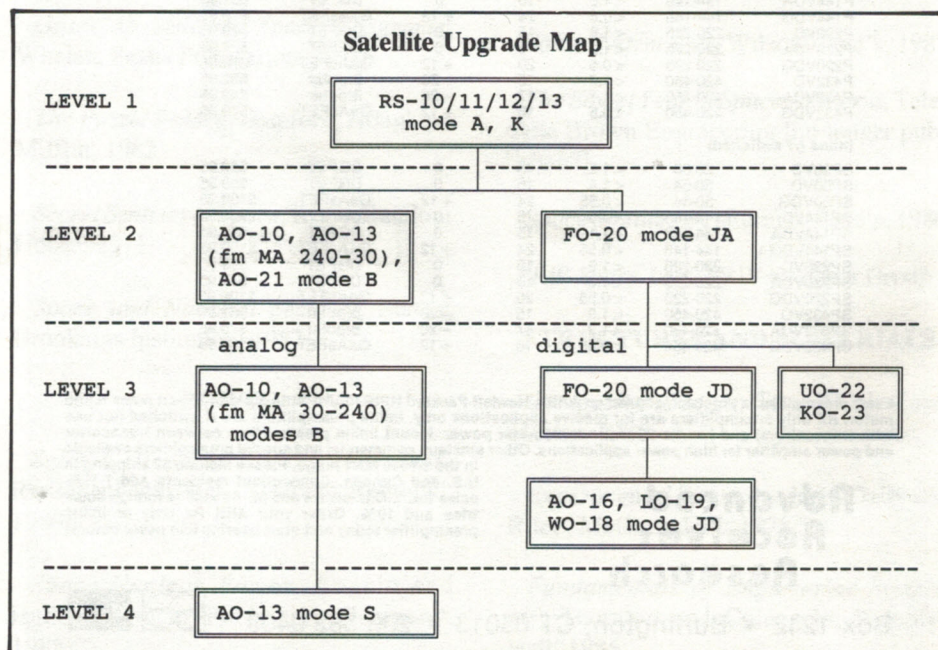
Here is an overview of the available satellites, the type of equipment and expertise necessary to work the amateur satellites. This information was put together from my experiences and from talking with others on the satellites. Consult the resources for more specific information.

The upgrade path is divided into levels. The levels were defined by the amount of equipment and the amount of knowledge necessary to operate at that level. All of us started out knowing little to nothing about satellite operation, the amount of effort you invest will determine how far you go. If you want to 'get your feet wet' and try satellite operation without investing much time or money the RS satellites in LEVEL 1 are the place to start. Study the available modes and equipment and chose a goal. Then work toward it. Some operators that have a great deal of equipment and/or money can jump into Level 3 and function effectively. When I first got interested in satellite operation, I didn't want to invest much money in a new project not knowing whether I would enjoy this mode or not. So, doing a gradual upgrading of my station proved beneficial. As my interest and experience grew, so did my satellite station. I have found amateur satellite operation to be the most enjoyable thing I have done in amateur radio. You will find a very interesting, well-behaved group of amateurs on the satellites.

My first recommendation on upgrading is: **put together the best receive station you can.** In HF operation the antenna gain is basically limited by the physical size of the antenna. Stations compensate by in-

creasing power. Since satellite work is done on higher frequencies, antennas are the best place to increase gain. You can get a good signal to the satellites with 10-20 watts and a decent transmit antenna. I often hear stations with signal levels well above the beacon because they use more power than necessary to be able to hear themselves on a less than adequate receiving system. The total amount of power transmitted by the satellite is fixed and divided among all the users, so hitting the satellite with more power then necessary decreases everyone's downlink signal. Also, by optimizing your receive system you will be able to hear and work stations easier. Especially those that are unable to use much uplink power or unable to point at the satellite. Keep your downlink signals at the beacon level, share the satellites responsibly.

The EIRP (Effective isotropic Radiated Power) value listed in the tables is based upon a realistic amount of power necessary for an acceptable level of voice communication, the beacon level. It is calculated using the formula $EiRP = 10^{(dB/10)} \times PWR$, where the ^ symbol means 'raised to the power'. An antenna with 12 dBi (dBi = dBd + 2.15) and fed with 10 watts gives $10^{(12/10)} \times 10$ or $10^{(1.2)} \times 10 = 158.5$ watts EiRP.



General Amateur Satellite Equipment Tables

Level 1 - Entry level, common, inexpensive equipment, minimal knowledge

RS-10/11/12/13 Mode A

Receiver: 10m SSB receiver
 Transmitter: 2m SSB transmitter
 RCVR antenna: minimal - vertical, dipole, quad, beam
 XMTR antenna: minimal - vertical, dipole, quad, beam
 amplifier: none
 EIRP: 41 w voice (25 watts into dipole antenna),
 10 w CW
 pre-amp: recommended 10m preamp
 modem: none
 computer: tracking program
 operation: CW, Voice
 resources: "The RS Satellites Operating Guide" from AMSAT-NA

RS-10/11/12/13 Mode K

Receiver: 10m SSB receiver
 Transmitter: 15m SSB transmitter
 RCVR antenna: minimal - vertical, dipole, quad, beam
 XMTR antenna: minimal - vertical, dipole, quad, beam
 amplifier: none
 EIRP: 41 w voice (25 watts into dipole antenna),
 10 w CW
 pre-amp: recommended 10m preamp
 modem: none
 computer: tracking program
 operation: CW, Voice
 resources: "The RS Satellites Operating Guide" from AMSAT-NA

Level 2 - Intermediate level, begin acquiring equipment and experience, begin thinking about whether you want to do analog or digital communication

FO-20 mode JA

Receiver: 435 MHz SSB or rcvr converter and HF rcvr
 Transmitter: 2m SSB transmitter
 RCVR antenna: vertical, dipole, quad, beam (beam is best)
 XMTR antenna: vertical, dipole, quad, beam (beam is best)
 amplifier: none
 EIRP: 300 w voice (20 watts into 12 dB antenna),
 100 w CW
 pre-amp: optional 70cm preamp
 modem: none
 other: none
 computer: tracking program
 operation: CW, Voice
 resources: "PACSAT Beginner's Guide" from AMSAT-NA

AO-10, AO-13 mode B (MA 240-30); AO-21 mode B

Receiver: 2m SSB receiver or rcvr converter and HF rcvr
 Transmitter: 435 MHz SSB transmitter
 RCVR antenna: vertical, dipole, quad, beam (beam is best)
 XMTR antenna: vertical, dipole, quad, beam (beam is best)
 amplifier: none
 EIRP: 250 w voice (10 watts into 14 dB antenna),
 60 w CW
 pre-amp: optional 70cm preamp
 modem: none
 other: none
 computer: tracking program
 operation: CW, Voice
 resources: "AO-13 Beginner's Guide" from AMSAT-NA

Level 3 - Experimenter. This is where you begin to get serious. More specialized equipment is necessary. You actually get to see first hand what working with weak, high frequency signals is like. A very interesting learning and experimenting stage. Concentrate on the best receiving station possible. The analog route used to also include AO-13 mode J, but that satellite's 70 cm transmitter is no longer operational.

AO-10, AO-13 mode B (MA 30-240)

Receiver: 145 MHz SSB;
 Transmitter: 435 MHz SSB;
 RCVR antenna: beam
 XMTR antenna: beam
 amplifier: 435 MHz mode B
 EIRP: 750 w voice (30 watts into 14 dB antenna),
 150 w CW
 pre-amp: 2m at the antenna
 modem: none
 other: azimuth and elevation rotors
 computer: tracking program
 operation: CW, Voice, RTTY, SSTV
 resources: "AO-13 Beginner's Guide" available from AMSAT-NA

FO-20 mode JD

Receiver: 435 MHz SSB or receive converter
 Transmitter: 2m FM transmitter
 RCVR antenna: beam, Lindenblad, J-pole
 XMTR antenna: beam, Lindenblad, J-pole
 amplifier: possibly
 EIRP: 400 w digital (25 watts into 12 dB antenna)
 pre-amp: 70cm preamp
 modem: 1200 bps PSK modem and TNC or DSP unit
 other: azimuth and elevation rotors
 computer: tracking program, terminal program
 operation: packet Bulletin Board
 resources: "PACSAT Beginner's Guide" from AMSAT-NA

UO-22, KO-23 mode JD

Receiver: 435 MHz FM or receive converter, tap at discriminator
Transmitter: 2m FM transmitter, tap at varactor
RCVR antenna: beam, Lindenblad, J-pole
XMTR antenna: beam, Lindenblad, J-pole
amplifier: possibly
EiRP: 300 w digital (20 watts into 12 dB antenna)
pre-amp: 70cm preamp
modem: 9600 bps FSK modem and TNC; DSP unit
other: azimuth and elevation rotors
computer: tracking program and PACSAT Broadcast Protocol software
operation: packet store and forward mailbox, CCD pics
resources: AMSAT News Bulletins, "AMSAT Journal", "PACSAT Beginner's Guide" available from AMSAT-NA

A0-16, LO-19, WO-18 mode JD

Receiver: 437 MHz SSB or receive converter
Transmitter: 2m FM transmitter (WO-18 receive only)
RCVR antenna: beam, Lindenblad, J-pole
XMTR antenna: beam, Lindenblad, J-pole
amplifier: possibly
EiRP: 300 w digital (20 watts into 12 dB antenna)
pre-amp: 70cm preamp
modem: 1200 bps PSK modem and TNC or DSP unit
other: azimuth and elevation rotors
computer: tracking program and PACSAT Broadcast Protocol software, Weberware
operation: packet store and forward mailbox (AO-16, LO-19), CCD pictures from WO-18
resources: "PACSAT Beginner's Guide" and "WEBERSAT Guide" from AMSAT-NA

Level 4 - Advanced experimenter, very specialized equipment and knowledge. Used to include AO-13 mode L, but that transmitter is no longer operational.

A0-13 mode S

Receiver: 2400 MHz SSB or receive converter
Transmitter: 435 MHz SSB transmitter
RCVR antenna: small dish or phased array
XMTR antenna: beam
amplifier: 435 MHz
EiRP: 300 w voice (10 watts into 15dB antenna), 100 w CW
pre-amp: 2400 MHz preamp
modem: none
other: azimuth and elevation rotors
computer: tracking program
operation: CW, Voice
resources: "AMSAT Journal", "AO-13 Beginner's Guide" available from AMSAT-NA

Heard on the Downlink

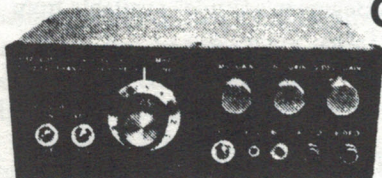
(continued from page 17)

crossbooms, and not a moment too soon as far as I'm concerned. Those of you who regularly read this column know of my continuing efforts to get my satellite antennas to point at the horizon when the elevation rotator says zero degrees. Just when I got the KLM 40cx fastened down to the point where it no longer slipped, I began to see some slipping at the point where the fiberglass crossboom enters the elevation rotator. I never feel comfortable tightening the rotator clamp *really* tight, for fear I'll break the crossboom.

Now Ron comes along with information about a company that makes a solid fiberglass rod that can be used as a crossboom. The rod is an inch and a half in diameter and comes in ten foot lengths for \$48.50. The "catch" is that UPS will not ship anything longer than nine feet. So Ron asked the company to chop off a foot and ship the remaining nine feet via UPS. There is a minimum mail order of \$50, so he paid that plus shipping. If you pick it up in person you can avoid the minimum charge and also get the full ten feet. The product is called EXTREN and it is made by Ain Plastics, Inc. Ron ordered his from Mt. Vernon, New York (800-431-2451), but they also list offices in Norfolk, VA, Southfield, MI, Lancaster, PA, Norwood, MA, Santa Clara, CA, Santa Fe Springs, CA, Chicago, IL, and North Brunswick, NJ.

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Principles of HELAPS Transponder Amplifiers

By Jan King, W3GEY

Editor's Note: This article is an edited version (with the author's permission) of portions of an article entitled "The Third Generation" by Jan King which was published in the November/December 1980 issue of Orbit Magazine. A recent article, "Phase 3D: A Satellite for All - Part 2" by Dick Jansson, WD4FAB, and Bill Tynan, W3XO, QST, June 1993, pg 47-51, referenced the King article. Since few current readers have access to the referenced issue of Orbit and since there continues to be considerable interest in the P3D transponder development it was thought that reprinting this article would be useful. The article begins by discussing the evolution of transponder technology from OSCAR-7 (launched 15 November 1974) to that planned for Phase IIIA, which failed to achieve orbit on 23 May 1980 (Black Friday). However the same HELAPS technology was carried over to Phase IIIB which became AO-10 after launch on 16 June 1983 and Phase IIIC which became AO-13 after launch on 15 June 1988.

Introduction

The Phase IIIA transponder continued in the tradition of AMSAT-OSCAR's 6 and 7 by improving the state-of-the-art in linear transponder technology, in that a number of significant advances were made compared to the Mode B transponder of AMSAT-OSCAR 7. It is necessary to review the status quo to appreciate the comparison. The 70 cm-to-two-meter transponder carried on the AMSAT-OSCAR 7 spacecraft had an output power of just about 10 watts PEP. Transponder automatic gain controls were established to maintain the peak-to-average-power ratio at 4:1. The average rf output was then 2.5 watts. Using the Envelope Elimination Restoration (EER) Principle, the power amplifier chain has an efficiency of about 50 percent. The bandwidth (3 dB points) is 43 kHz. The spacecraft typically can be accessed by users up to a range of about 3500 km (2200 mi.) give or take various odd propagation modes occurring near AOS and LOS.

Recalling that the Phase IIIA spacecraft was to attain an apogee of 35,000 km and would be in view of a large percentage of the world's amateurs for most of the time, improvements in power output and passband bandwidth were in order. To achieve signal levels comparable to those of AMSAT-OSCAR 7, near AOS, some 20 dB increase in EIRP on the down link would be necessary.

The desired bandwidth to accommodate the worldwide user community would have been quite large. However, practical limitations (e.g. worldwide two-meter frequency allocation and passband filter realization) set this limit at some what under 200 kHz. Considering beacon requirements and Doppler shift, a 150 kHz band-

width seemed a reasonable goal. A major portion of the additional path loss as compared to AMSAT-OSCAR 7 was to be made up by antenna gain at the Phase IIIA spacecraft. Both up and down link 'high gain' antennas achieved a minimum gain of +10 dBi. This left 10 dB to be made up by the transmitter on the down link.

Because of constraints on available dc power, only seven dB of the desired improvement could be realized. The transmitter PEP output was set then at 50 watts giving a down link EIRP of 500 watts (some 3 dB short of the overall goal). This down link level was considered by the designers to be quite an acceptable compromise. The user is left with the option of increasing his receive antenna gain by 3 dB (with only a small pointing penalty) or simply accepting this lower signal level which is within the normal user system 'error plus uncertainty' budget. In fact, with a circularly polarized antenna at the ground and at the spacecraft the Phase III user picks up most of the 3 dB due to matched polarization, an improvement over the non-optimum AMSAT-OSCAR 7.

When comparing Phase III to AMSAT-OSCAR 7, up link path loss increases are also an additional 20 dB. Again + 10 dBi of antenna gain on 435 MHz was planned and achieved. While slight improvements in front end noise figure were accomplished with the new transponder and total input noise was reduced because of the greater distance of the earth from the satellite, some seven to nine dB of additional up link power would have been required by Phase IIIA users to achieve similar results to AMSAT-OSCAR 7. In effect, this has the advantage of reducing the abil-

ity of 'big gun' stations to overload the transponder by the same seven to nine dB! The increased transponder bandwidth also reduces the sharing problem since a strong station will have to share with many more stations.

HELAPS Transponder Technology

It is important to review the existing in-orbit technology of AMSAT-OSCAR 7. New users may not be aware of what they are using right now, others may need a refresher. In order to transpond a portion of spectrum from one frequency to another where frequency sharing techniques are employed a linear amplifier must be used to maintain both the phase and amplitude relationships of the original signals and to avoid undesirable intermodulation products. It is known that linear amplifiers exhibit poor dc to rf power conversion efficiency resulting primarily from the bias point of the amplifier. This implies that a quiescent current will be drawn independent of drive level. Class A, AB and B amplifiers typically have peak efficiencies from 20 to 50 percent. To make efficiency matters much worse, the amplifier is seldom driven to peak values. In the case of our satellites, the drive signal is a summation of amplitude modulated signals (cw, ssb, other). This 'ensemble' of signals obeys statistical laws in accordance to a property known as the central limit theorem. The significance of this is that the average power output of the ensemble is about seven dB below the peak level in a real system. A classical linear amplifier has, in fact, very poor efficiency at these drive levels (between five and 20 percent under ideal conditions). Clearly, such amplifiers cannot be tolerated in a satellite design where dc power is such a precious

resource. I now introduce a principle which I truly feel can be attributed to Karl Meinzer, DJ4ZC [1]. The Meinzer Theorem states that it is possible to increase the efficiency of a linear amplifier beyond its 'classical' theoretical maximum if the amplifier source voltage is reduced in accordance with (i.e. proportionally with) the input drive signal. The converse is also true. This is clearly evident. The inefficiency of classical linear amplifiers can be traced to the percentage of time that the drive signal is low and the plate or collector supply remains constant. In fact, it is possible to achieve amplifiers that have a nearly constant and high efficiency over a wide range of drive levels. This is precisely the desired performance for our needs. This class of amplifiers is sometimes referred to as 'Class-D' although there is some confusion over the definition of what should be included here, see Fig. 1. To be more precise the performance of the amplifier may be improved by the desired amount by manipulating any output parameter (e.g. dynamic impedance) such that the power source to the amplifier is drive dependent.

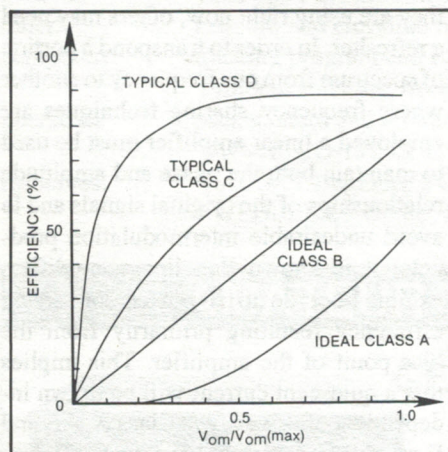


Fig 1: Efficiency of Class D power amplifiers remains high down to relatively low output levels (from Raab [4]).

There are a number of approaches to the design of such an amplifier to be sure. As you might suspect, a number of performance tradeoffs result from any specific design candidate. In the transponder aboard AMSAT-OSCAR 7 the EER concept originated by L. Kahn [2] was adopted by DJ4ZC for the Mode B power amplifier. Fig. 2 shows this concept. At i-f a sample of the drive signal is envelope detected and amplified. The main amplifier chain consisting of Class-C amplifiers operates on the i-f signal after it has passed through a

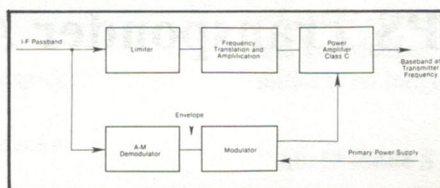


Fig 2: The envelope elimination and restoration process.

limiter. In fact, two separate channels have been created. The one containing the Class-C amplifiers contains only the phase information from the original signal while the second 'envelope' channel contains only the original amplitude information. The original signal is recreated, in fact, when the envelope component, after suitable linear amplification, is used to modulate the last few amplifier stages in the phase channel. High efficiency linear and drive-independent performance may be obtained using an EER amplifier providing that phase delay between the two channels is minimal and that certain requirements of the envelope amplifier are met. It is the characteristics of the envelope amplifier that are the main 'trick' to the transponder. DJ4ZC found that it was important that the bandwidth of the envelope amplifier (referred to as simply the

modulator) be from three to five times the i-f or pass band bandwidth and that this linear amplifier itself must be of a high efficiency type lest it degrade the overall amplifier efficiency. To accomplish this a switching duty factor amplifier was employed. The envelope signal was fed to a high power switching circuit which produced a rectangular output whose duty factor was proportional to the amplitude of the envelope during a given sample period. The object of the saturated switch was that it dissipates no power except during switching transitions and thus, is inherently very efficient. The duty factor waveform was finally put through a low-pass filter to recover the original envelope at high level for the modulation process. With a 10-watt transponder using an i-f band width of 45 kHz, the demands placed on the modulator were stringent but achievable. A minimum modulation bandwidth of 150 kHz is required and the amplifier was required to switch two-ampere peaks in a few nanoseconds so as to minimize switching periods. In 1973 when the AMSAT-OSCAR 7 transponder was built, the solid-state devices to accomplish this latter task reliably had only just become available.



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The Phase III transponder requirements of 150 kHz bandwidth and 50 watts PEP output proved to be a bit too much for this type of amplifier. Now the modulator bandwidth became about 500 kHz and switching currents as high as ten amperes in even fewer nanoseconds became a requirement. While some devices were found that would handle this problem, long term reliability still remained a concern. When a modulator of this form was tested the most serious problem, however, turned out to be the incredibly high level of rfi generated by the very fast switching action. Attempting to remove this 'hash' from the remainder of the system has proved futile to date.

The solution to this problem was to develop an entirely different amplifier which is a first as a space application. Another approach to solving the high efficiency amplifier problem was introduced by W.H. Doherty in 1936 [3]. The Doherty amplifier also 'obeys' the Meinzer Theorem. Consider the concept shown in Fig. 3. A single transistor amplifier is utilized so that it is operating at high efficiency when driven to a level corresponding to the average power output of the passband envelope (or approximately six to seven dB below peak value). The transistor can be operated at high efficiency at any particular output power provided that the collector voltage swing is large. Put differently, the load impedance must be high enough to require a large voltage output from the device. If we take the requirements of the Phase III amplifier as an example, a device capable of delivering 25 watts into an impedance of Z ohms at high efficiency, will deliver 12.5 watts into $2Z$ ohms at the same voltage output and thus the same efficiency. The problem with this arrangement is that upward modulation peaks would not be amplified because the collector swing has already reached its maximum value at 12.5 watts output.

At this point Doherty proposed that an additional and variable source of voltage be inserted in series with the load impedance (Fig. 3B). The additional source is to have a peak value equal to the output voltage of the first device and its amplitude is to increase as the drive increases above the average value. The primary purpose of this voltage generator is to handle the transponder modulation peaks. At peak drive now, the current increases to twice the average value as does the voltage.

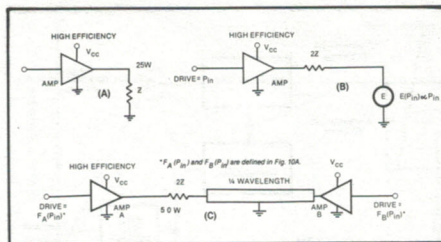


Fig 3: Doherty Amplifier Concept. See text for additional details.

Consequently the power increases from the average value of 12.5 watts to 50 watts or by six dB. It is interesting to note that

the effect experienced by the original transistor as the added generator comes into play is a gradual lowering of the impedance into which it is operating, since its output current increases without an increase in output voltage. In fact, when the generator output reaches its maximum value, the circuit impedance has exactly been reduced from $2Z$ to Z ohms.

The problem now remaining in the output circuit is to synthesize a realizable voltage generator. We cannot directly replace the ideal generator with a typical active device because, while a generator

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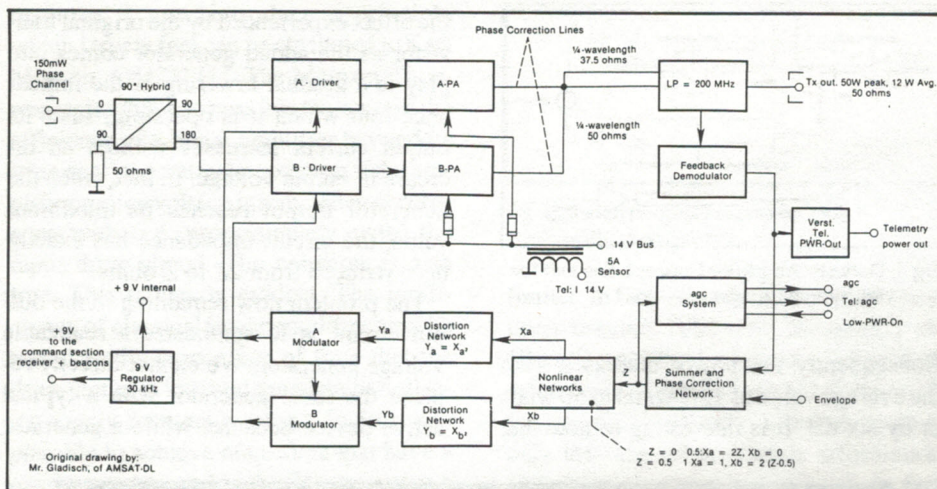


Fig 4: Phase III Transponder EER - Doherty Amplifier/Modulator Block Diagram.

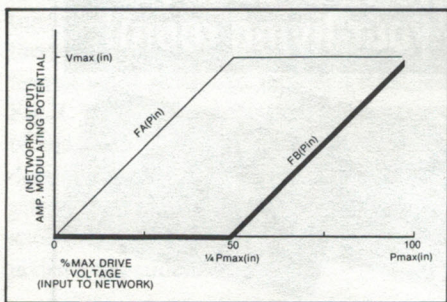


Fig 5: Modulation Network Transfer Characteristic.

would offer no impedance to the flow of current from the original transistor, an active device, when turned off offers a very high impedance. What is required is an impedance transformer that has an impedance at the source port that is inversely proportional to the terminating impedance on the output port. This is a well known property of a quarter-wave transmission line. It turns out that a 1/4 wavelength coax line possesses all of the desired characteristics for such a scheme and is convenient to implement in the case of a 145 MHz amplifier. The generator device then becomes an identical rf amplifier to that of the original amplifier. At 1/4 drive (the average output) the first amplifier is delivering all of the output. As the drive increases the first and second amplifier begin to share the load. At full output each amplifier is furnishing 1/2 of the output power which is twice the average power level.

Some additional consideration must be given to the input circuitry of the amplifier. While in Doherty's case, 'the grids of both tubes are excited by the modulated output of the preceding stage' (keep in

mind the date of his work) with appropriate bias conditions, the Phase III transponder again makes use of EER technology to accomplish the modulation function. Each of the two amplifiers have two stages of gain. The driver stages are fed with the phase component of the signal while the envelope component is applied to the collectors of the driver stages via two different non-linear networks that

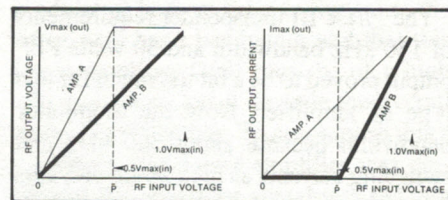
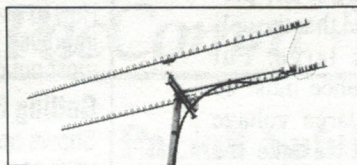


Fig 6: Voltage and current relations in the two amplifiers.

produce amplifier transfer characteristics as shown in Fig. 5. The effect of the networks are, of course, to produce the correct bias conditions for amplifier power sharing as described above. In Fig. 4 one notes a few auxiliary design requirements of the EER-Doherty amplifier. A 90 degree phase shift of the input to one amplifier is necessary to compensate for the 90 degree shift at the output of the other amplifier created by the quarter-wave transmission line. The square law networks following the non-linear bias network in the modulator chain and the feedback around the amplifier are both used to improve overall amplifier linearity. The 37.5-ohm 1/4 wave length line is used to match the low output impedance of the amplifier to a 50-ohm load.

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The performance of the flight EER-Doherty amplifier was excellent. Fig. 7 shows the efficiency as a function of drive level. This efficiency curve is typical of Doherty amplifiers. Note that below the average power point the efficiency drops off rapidly while above this level it is fairly constant.

Thus a technology intended for improving the efficiency of 'multi kilowatt' a-m broadcast transmitters finds its use today in providing a new solution to communications via satellite--something perhaps Doherty would never have dreamed of.

Acknowledgement

My thanks to Karl Meinzer, DJ4ZC, for his assistance in preparing this section. As most are aware, Karl and AMSAT-DL are

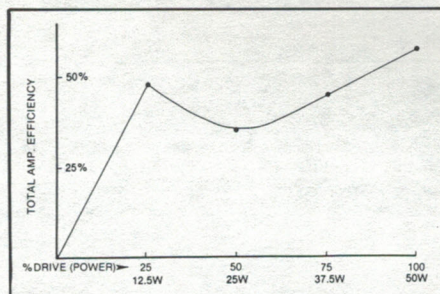


Fig 7: Total amplifier efficiency as a function of drive level.

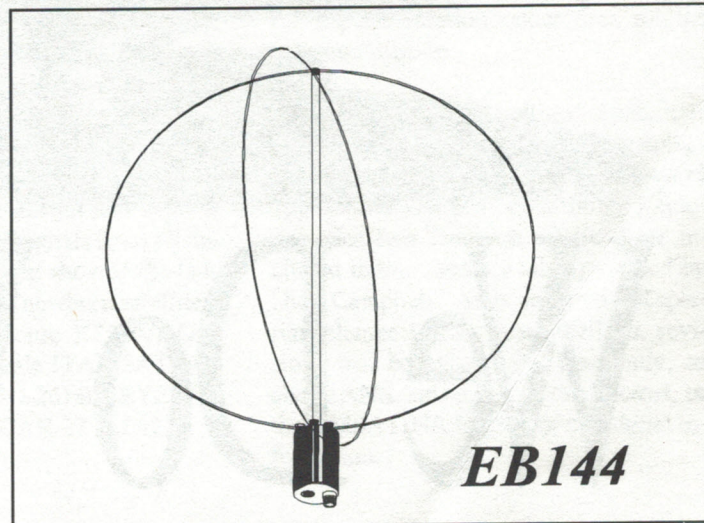
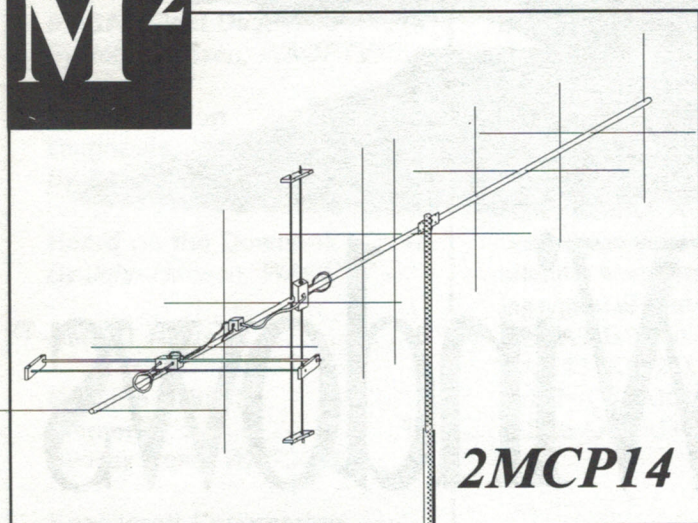
responsible for the design and construction of the transponder.

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4. Raab, F.H., 'Get Broadband Dual-Mode Operation with this FET Power Amplifier,' Electronic Design News, October 20, 1978, pp 117-124.

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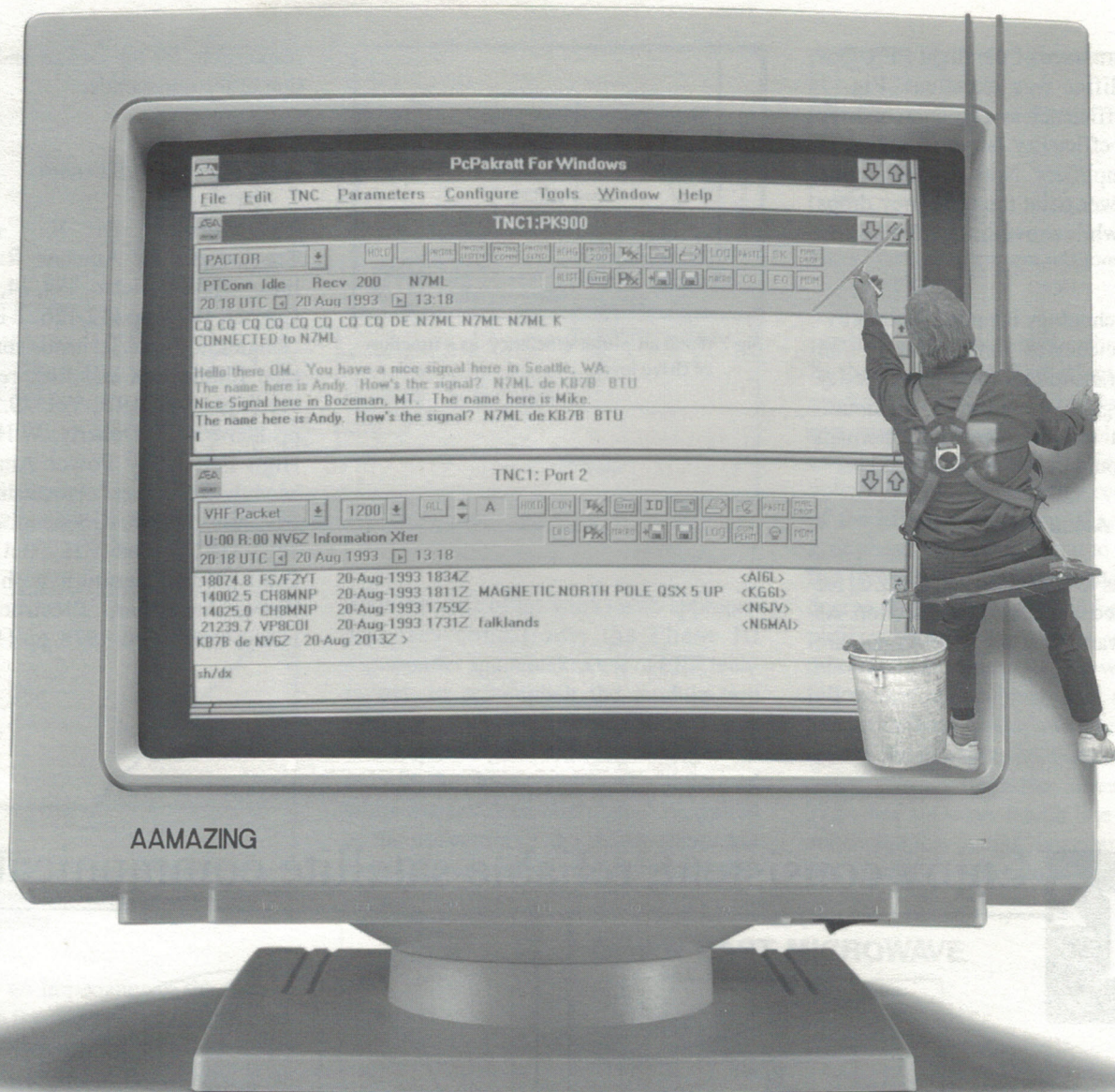
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